H. C. H. SHENTON,

President of The Society of Engineers (Incorporated) 1914.

(See page 5.)

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HENRY CHAWNER HINE SHENTON,

President of the Society of Engineers (Incorporated) for the year 1914.

Mr. H. C. H. Shenton (Senior Partner in the firm of Messrs. Shenton and Easdale, Civil Engineers) was born in 1870, and was educated at private and public schools and at the Crystal Palace School of Practical Engineering. He was articled to the late Sir William Shelford and worked afterwards with him as an assistant. He also worked in the capacity of an assistant for 18 months in the Works Department of the Admiralty at Portsmouth Dockyard, and four years with Mr. Frederick H. Anson, of Westminster; also for 18 months in the Admiralty Works Department at Chatham Dockyard. In the year 1900 he entered into partnership in private practice with Mr. Frederick H. Anson, Engineer to the Herts and Essex Waterworks Company (now retired), and since that time Mr. Shenton has worked in private practice in Westminster, dealing chiefly with waterworks and with sewerage and sewage disposal works, both at home and abroad.

ELECTRIC LIGHTING OF STEAM DRIVEN TRAINS.

By E. Kilburn Scott, M.I.E.E., A.M.Inst.C.E.

The risk of fire which attends the use of pressure gas for train lighting is now widely recognised, because gas escaping from the gas cylinder has been responsible for much loss of life and property in railway collisions.

Electricity, on the other hand, is practically free from risk of fire, because in the event of the destruction of a coach the circuits are broken. Only the battery has any capacity to originate a fire and that only when it is in good order. It is certainly incapable of augmenting a fire should one be otherwise started. That this is the definite opinion of the authorities is shown by the following extract from Major J. W. Pringle's report on the Midland Railway disaster at Aisgill on Sept. 2nd, 1913, when 16 passengers were killed and 38 others seriously injured.

"The case for gas as a standard illuminant is not bettered by the circumstances attending this accident. Gas escaped from the cylinders under two of the wrecked carriages, and ignited.

"A statement of all the accidents inquired into by the Board of Trade during the past 15 years in which the wreckage caught fire shows that, so far as danger from fire is concerned, gas is less desirable as an illuminant than electricity.

"I wish again strongly to urge upon railway companies the desirability of employing electricity as their standard illumination."

Historical.—Somewhere about the year 1881 the London, Brighton and South Coast Railway Company had a Pullman car equipped with twelve Swan lamps. Current was supplied from 30 Faure accumulators, and the cells were charged at Victoria Station.

In 1883 Messrs. Stroudley and Houghton introduced the first axle-driven dynamo on the Brighton Railway. The lamps gave 16-candle power and were run in parallel. Three trains were equipped on this system. Similar equipments were placed on the South-Eastern Railway trains in 1884 and on Great Northern Railway trains in 1886.

In 1889 Mr. Langdon equipped 12 main line trains on the Midland Railway by axle-driven dynamos in the luggage vans. He installed lead-cell accumulators under every coach, and there was through wiring with couplers between coaches. The accumulators gave to coaches independent lighting, and the

trains were thus capable of being divided up and coaches rearranged.

It was not until 1890 that the present system of equipping each coach with its own dynamo as well as a battery came into vogue. Mr. A. B. Gill was principally identified with this and through him the makers of his apparatus—Messrs. Stone & Co.

Standard requirements.—A satisfactory train lighting system must meet the following conditions:—The energy must be generated by means of the train itself and this requirement calls for a dynamo driven from the carriage axle. This requires a reliable device which will compensate for the large variations in the speed of the driving axle. Means must be provided for automatically compensating for the varying demands for light occasioned by the changes in the length of day at different seasons. Variations in conditions of service under which any given coach may be running, and provision against sudden fogs or dark weather must be met. Lastly the light must be supplied whether the train be in motion or at rest, and in the latter case during stoppages of short or long duration.

By general consensus of opinion the only successful method of lighting railway trains is the unit system, on which each coach has its own dynamo and battery. A number of important details have also become more or less standardised. For example, the voltage is always 22 to 24 volts. Although arrived at before the advent of the metal filament lamp, this pressure is eminently suitable for that form of filament. It is also the right voltage for dozen lead cells, the pressure of which when fully discharged is 22 volts.

The variation of voltage at the lamps is kept within $2\frac{1}{2}$ per cent. above and below the normal rated voltage. With a 10 candle-power tungsten lamp, a variation of $2\frac{1}{2}$ per cent. gives a 10 per cent. increase and $2\frac{1}{2}$ per cent. below gives 8 per cent. decrease in candle power. The percentages are 15 and 14 per cent. for carbon lamps.

As a comparison it may be mentioned that for ordinary electric lighting supply from a power house 4 per cent. regulation above and below the normal is considered good practice.

Dynamos.—The best type of dynamo to charge cells is the shunt wound dynamo. As the direction of rotation is constantly being reversed, the magnetic and electrical characteristics must be the same which ever way the dynamo rotates.

The dynamos have to be entirely enclosed because when an engine is taking in water from a trough the dynamo on the coach next to the engine is enveloped in spray. Ball bearings are almost invariably used because of the reduced friction and less space taken up. Grease lubrication is better than oil because the oil is liable to be washed out of the wells.

Further particulars of dynamos will be given below.

Gearing.—The standard form of driving is by means of a belt and the commonest arrangement is to have the dynamo so suspended that the belt slips at the higher speeds. This slipping belt regulation has held its own mainly owing to the simplicity of the device, and it has survived a good many more scientific methods.

The dynamo is hung, pendulum fashion, out of centre, so that its weight supplies a known and constant belt-tension, In addition there is usually a spiral spring attachment on the dynamo to allow of adjusting the belt tension so as to reduce waste of power by belt-slip. As the oscillatory motion of a bogie-frame is considerable, the dynamo is generally hung from the coach-body.

Dynamos have, however, come into use which can dispense with slipping belt regulation. The dynamo can thus be suspended directly from the coach bogie and the belt tension remains normal irrespective of the speed. This is the case with the systems described in detail below.

Gear wheels have been proposed, but the difficulty with them is that the train wheels are liable to be skidded by too sudden application of brakes on the train. When this takes place with a belt drive the belt merely slips on the pulley and no harm is done. With gear wheels there might be a breakage. Casting of belts may be reduced by having the flanges of pulleys turned exactly at right angles to the pulley-axis instead of being sloped outwards. When the tight side is at the top the belt is more liable to get off.

The gear-ratio is usually such that at 15 miles per hour for a slow stopping service the battery begins to charge. On a fast service the cutting in speed is usually 25 miles per hour. For a suburban service the dynamo may have to cut in at 5 miles per hour, but a suburban service with stops less than one mile apart invariably has rolling stock kept specially for it, and special speed-reduction gear is provided for driving the dynamo. It is most important that the dynamo, when connected to the battery, should give its maximum output at a low speed. This speed must be set as high as practicable, so that when a heavy train slows down on a bank the dynamos may cut out and relieve the load on the locomotive.

Efficiency.—At the higher speeds a great deal of power is wasted by slipping belt regulation and the belt is very rapidly frayed or worn away. The following table gives an idea of the large amount of power wasted.

Speed.		Horse Power Taken from Locomotive in Excess of Output of Dynamo.	
Train Miles per hour.	Axle Revs per min.	Subsidiary Brush Regulation Leitner System.	Slipping Belt Regulation.
26	197	0.88	0.43
40	300	0.95	1.63
51	382	0.67	2.89
60	450	0.65	3.56
80	600	0.65	5.65

It is of special interest to note that comparatively recently the firms which are identified with the two systems compared in the above table have amalgamated, and no doubt this will result in a modified system covering the good features of both methods.

It might be thought that the power taken for lighting a train is so small compared with the total power of the locomotive as not to matter much, but this is quite wrong. Good efficiency is important.

The efficiencies that are capable of attainment appear to be—

Dynamo to lamps .... 75 per cent. to 82 per cent.
Battery to lamps .... 90 per cent. to 95 per cent.

Switch Regulator.—The switch regulator forms a most important part of any system, and it may be therefore of interest to give a summary of the conditions with which it must comply.

These have been very well stated by Mr. Roger V. Smith, B.Sc., A.M.Inst.C.E., in a paper before the Institution of Civil Engineers as follows :—

(*a*) It must control the lamp-voltage within 2½ per cent. above or below normal.

(*b*) It must do this with a twelve-cell battery between the limits of a safe minimum discharge-pressure of 22 volts when all regulating resistance is cut out and the maximum of 33 volts required for a desulphating charge.

(*c*) Within reasonable limits the voltage-regulation must be independent of lamp load.

(*d*) When lamps are off, the regulator must control the generator field, so as to allow the full output of the dynamo to charge the empty battery.

(*e*) As charging proceeds it must gradually oppose the inherent rise in dynamo voltage, but only at such a rate as to properly tail off the charging current.

(*f*) The regulator must combine the advantages of constant current charging and constant voltage charging without the disadvantages of either.

(*g*) Towards the end of the charge the regulator should reduce the current to not more than 5 per cent. of the full load output of the dynamo, until the battery is fully charged.

(*h*) After the battery is fully charged and the lamps are off, the regulator must reduce the charging current to zero while still allowing the dynamo-field to be excited sufficiently to build up at once, and in the right direction, if suddenly called upon to do so by the switching on the lamp load.

(*j*) When the battery is fully charged and the lamps are on, the output of the dynamo must be adjusted automatically so as to correspond exactly with the lamp load, so that the fully charged battery is left floating on the load. Current then neither enters nor leaves the battery, and the whole of the lamp load is taken by the dynamo.

Description of Systems.—The ingenuity that has been displayed by inventors to meet the very difficult conditions of train lighting is quite remarkable and there are many efficient systems on the market to choose from.

In picking out the following for detailed description the writer does not wish it to be supposed that he considers them better than others, but they have been chosen because they present novel features of interest to all engineers. In some cases certain of the details would appear to have wider applications than for train lighting. This is the case, for example, with the very clever differential dynamo invented by Mr. Newton.

Mather & Platt System.—The main features of this train lighting dynamo are, first, that the current output of the dynamo is constant within very wide limits of speed, and its voltage constant within the same limits when working on a circuit having approximately constant resistance ; second, that the direction of the current is independent of the direction of rotation.

As a result of the first-mentioned feature, no regulating devices of any kind are necessary to prevent over-charging or under-charging of the storage cells, it being necessary only to provide some means of preventing the battery discharging through the dynamo when the train is at rest or moving very slowly. Further, as a result of the second characteristic, no pole-changing device is required, the current always remaining in the correct direction for charging the cells.

The armature is drum wound and the pole-pieces, limbs, and yoke are similar to those of any ordinary dynamo, save that the

pole-limbs and yoke are of a much smaller cross section. There are usually two poles and brushes *b b* (Fig. 1), which in a normal machine would supply current to the external circuit, are short circuited, and these are referred to as "aid" brushes in the following description. A second pair of brushes placed at right angles to the first pair constitute the main working brushes from which current is led to the lamps and battery. A shunt winding connected directly to the dynamo terminals forms the primary exciting winding.

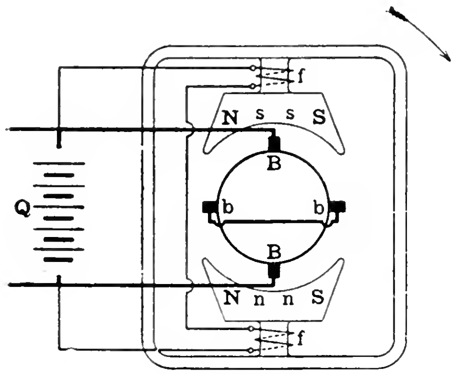


Fig. 1.

The field windings *f f* establish a flux in the field magnets and armature, passing vertically through the latter as indicated by the letters *ss*, *nn*, Fig. 1. The rotation of the armature in this field induces in its conductors currents which circulate through the "aid" brushes *bb*. Obviously, a very small flux is sufficient to produce a large short circuit or "aid" current, and therefore, the dimensions of the shunt windings *ff* are relatively small.

The currents flowing in the armature, short circuited by the brushes *b b*, produce a flux through the armature at right angles to the primary flux. This flux circulates round the pole-pieces and armature as indicated by the letters **N N**, **S S**, and does not traverse either the pole-limbs or yoke which carry the primary flux. The rotation of the armature in this secondary flux produces a difference of potential between the brushes **B B**, and sends current into the external circuit.

For the sake of clearness, the currents flowing in the armature may be considered as existing in two independent windings, and it will be observed that the currents flowing through the "aid" brushes *b b* produce a flux at right angles to the primary flux, and therefore produce no effect on this latter flux as regards magnitude. The currents flowing through the main brushes **B B** produce a flux exactly opposed to the primary flux, and accordingly diminish it in exact proportion to the strength of the current in the external circuit.

It follows, therefore, that for a certain value of the external current, the ampere-turns of the armature will exactly correspond to the ampere-turns of the primary exciting winding, and being equal and opposite, the resultant flux will be zero. As without a primary flux the dynamo would cease to generate current, it is clear that the limiting value to the external current which the dynamo can produce is that current which makes the

armature ampere-turns equivalent to the field ampere-turns. Further, as a very small excess of field ampere-turns over armature ampere-turns is necessary to produce the current in the "aid" brushes which sets up the working field, a very small diminution in the circuit in the external circuit is sufficient to produce this working flux.

At normal speed an "aid" current equal to about 40 per cent. of the external current is sufficient to produce the working flux, and for this current an excess of field ampere-turns over armature ampere-turns of only 10 per cent. is required. Now, if the speed increases to four times the normal or even to an infinite value, the current cannot increase by more than 10 per cent., for a 10 per cent. increase would entirely neutralise the primary flux. On the other hand, if the speed falls to, say, 70 per cent. of the normal value, the current would fall; but should it fall by even as little as 10 per cent. of its normal value, the primary flux would immediately be doubled, producing a rise in the aid current of about 40 per cent., and increasing the horizontal armature flux sufficiently to compensate almost exactly for the change in speed. The fact that the compensation for speed variation depends on the differential action of two practically equal quantities is the principal reason for the automatic regulation which is obtained with this dynamo.

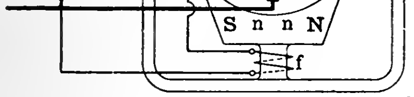
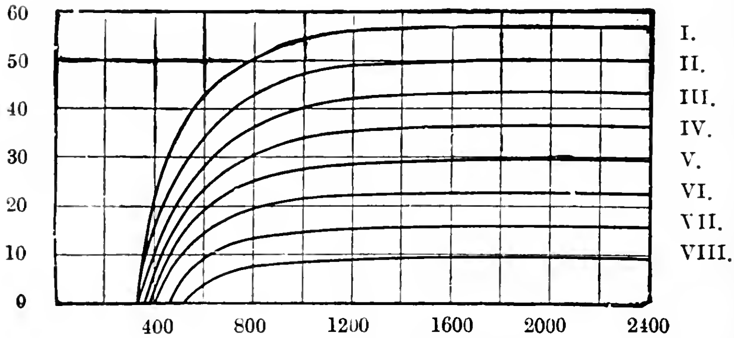


FIG. 2.

The effect of reversing the direction of rotation of the dynamo is shown in Fig. 2. Since the current in the primary exciting windings remains unchanged, the direction of the aid current is reversed. The horizontal armature flux produced by the aid current is therefore also reversed, and this reversal, in conjunction with the change in direction of rotation of the armature, causes the direction of the current in the external circuit to be the same as before.

Fig. 3 shows what might be called the external characteristics of these machines working in parallel with a battery, *i.e.*, with constant external voltage. The various characteristics are obtained with different exciting currents in the coils *f f*. Starting with curve I, which represents the working of the machine with maximum excitation, we see that at so small a speed of the machine as about 340 revolutions, corresponding to a train speed of about $9\frac{1}{4}$ miles per hour, the terminal voltage of the machine becomes equal to the battery voltage, and that the



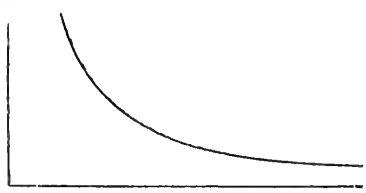
Revs. per min.

FIG. 3.

current supplied by the machine increases rapidly as the speed increases above this point. When a speed of about 700 revolutions per minute, or 19 miles per hour, is reached, the current attains practically a maximum, since the curve runs asymptotically towards a definite limiting current. Thus, a change of speed from 2,400 to 800 revolutions per minute, or 65 to 21 miles per hour, only produces a drop in current of about 12 per cent. Curves II. to VIII. represent the working of the machine with a smaller excitation in the coils *ff*. At half excitation (curve V.), the speed at which the battery voltage is reached is only slightly higher than before, and the maximum external current is almost exactly half that for full excitation.

In Fig. 4 is shown the variation of the current through the aid brushes with the speed. It will be seen that at low speeds the aid current rises rapidly as the speed decreases. In order to avoid the possibility of the aid current reaching a dangerous value in any circumstances, it is found advisable to let the iron of the magnet yoke or core become saturated when the flux reaches a value corresponding to the maximum safe aid current. Then, if the speed falls below that corresponding to this point, the aid current will decrease, until finally the voltage of the machine will fall below that of the battery. To prevent current being sent back from the battery through the dynamo, a reverse-current cut-out is inserted between them, as already described.

Amps.



Revs. per min.

FIG. 4.

The aid brushes work in a neutral zone. There is no difference of potential between them, as they are short circuited, and the current flowing between the brushes is quite small except at very low speeds. The product of the commutated current and speed which determines the reactance voltage is nearly constant

for all speeds, and therefore the commutation at these brushes is equally easy throughout the range of operation of the dynamo.

The main brushes work in a field which is particularly favourable to good commutation. If the reaction of the secondary flux on the primary be considered, it will be noted that the two produce a resultant flux which is not vertical, but is inclined at a slight angle, the direction of inclination being opposite to the direction of rotation of the armature. The effect of this inclination of the flux is precisely equivalent to giving the main brushes a forward lead, or to the action of commutating poles, in assisting collection of current. Both sets of brushes have been found to work absolutely sparklessly when running in either direction, and at any speed which is within the bounds of mechanical safety.

The diagram of connections, Fig. 5, shows how the dynamo, batteries and lamps are connected together for the Mather and Platt system.

When the train is at rest or moving very slowly, the solenoid cut-out " S " is in the lower position, and the two batteries " B_1, B_2 " then feed the lights in parallel through the main switch. Under these conditions the dynamo is disconnected from the lighting circuit at the point " D."

As the speed of the train increases, the voltage of the dynamo rises, causing the current to flow through the shunt winding of the solenoid cut-out " S." When the voltage of the dynamo is slightly higher than that of the battery, the plunger of the solenoid cut-out is pulled up, closing the circuit at " C.D." and breaking the circuit at " L.R." This voltage is reached at a speed of about 8 miles per hour. At the moment of " cutting in," the dynamo supplies only a small current, thus preventing any burning of the switch contacts.

On the speed of the train decreasing below 8 miles per hour, the current which the dynamo generates falls rapidly until, at a speed of about 5 miles per hour, it reaches zero, and then tends to reverse. Immediately a small reverse current passes through the dynamo, the series winding (the current through which is normally assisting the shunt and increasing the contact pressure) acts in opposition to the shunt winding, thereby demagnetising the plunger and causing it to fall. The dynamo is then cut out of circuit, and at the same moment the resistance " L.R." is short circuited, and both batteries are connected directly to the lamp circuit.

The regulation is effected solely by the dynamo, the battery existing more for the purpose of supplying light when the train is at rest or moving very slowly.

The dynamo output is adjusted by means of an output adjuster, " O.A." This consists of a shunt resistance with eleven

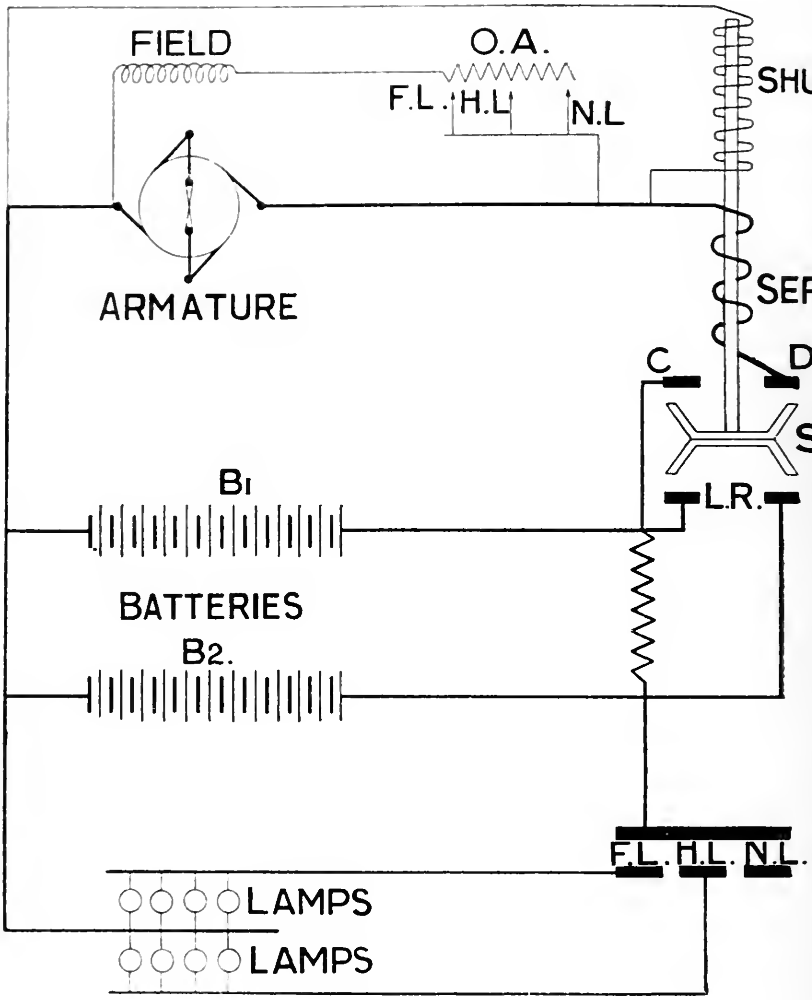


FIG. 5.

terminals, on any of which the three movable connections marked " F.L.," " H.L.," " N.L.," may be fixed. These are connected to the main barrel switch and are brought into operation by the latter, according as it is turned to the " Full Light," " Half Light," or " No Light " position.

For normal working, the outputs in the three positions of the main switch should be arranged so that the dynamo output exceeds the lamp load by an amount sufficient to keep the batteries in good condition, and also enable the batteries to feed the lights during stoppages.

The lamp resistance " L.R." is made in two sections for " Full Light " and " Half Light." These sections may be independently connected by series paralleling links to suit the actual conditions of loading on " Full " and " Half Light." They are brought into operation by the main barrel switch in the same

way as in the case of the output adjuster. On " No Light " they are short circuited altogether ; on " Half Light," one section is brought into use, and on " Full Light," the other section is connected in parallel with the first.

The purpose of the lamp resistance " L.R." is to enable one of the batteries to be used merely as a regulating battery, the other battery absorbing the greater portion of the charging current, and consequently taking over most of the load when the train is standing.

The system is adapted for working with either a single or double battery. Where the number of lamps in the coach is large, or the stoppages of long duration, necessitating a battery of large capacity, a double battery is used. The size and weight of the individual cells are thereby reduced, and they can be more easily handled. Where the coach is required for intermittent service, or for a service of very varying character, a double battery is used. For small coaches and where the service is regular, a single battery is found advantageous on account of its smaller initial cost.

Ferguson System.—The train lighting apparatus supplied by the Leeds Forge Co. is due to Mr. Ferguson. He uses a constant current dynamo and automatic regulation is effected entirely by the torque or turning moment required to drive the dynamo.

The output of the Ferguson dynamo is definite and constant and not dependent upon the ever-changing state of the belt and pulley service and there is no danger of burning out the armature or destroying the battery.

The output is adjusted by setting a screw-nut and the dynamo examiner knows exactly what the current will be, by the position of this, so there is no necessity to go out on trial with the coach after each adjustment.

The armature and commutator are mounted upon a sleeve which is free on the main shaft. The armature is driven by a pin, which works in the spiral groove or can cut in the sleeve attached to the armature as shown in Fig. 6. When the shaft is rotating this pin bears against the side of the slot A, either in one direction or the other and so causes the armature to rotate with the shaft. The power required to drive the dynamo cannot alter, as the pin B has a tendency to ride along the slot A, which as the shaft is fixed in the bearings, causes the armature to be pushed out of the influence of the field magnet poles N S. This is done against the force of the regulating spring D. As the speed increases, the armature is moved farther out of the field ; similarly, as it decreases the armature moves back into the field. To change the output the force of the spring D can be adjusted by the nut C.

The slot A in the sleeve goes in both directions, as can be seen from Fig. 6, and the action is therefore exactly the same in whichever direction the dynamo runs. The brushes are fixed upon a rocking disc E, and adjust themselves automatically so as to keep the polarity right.

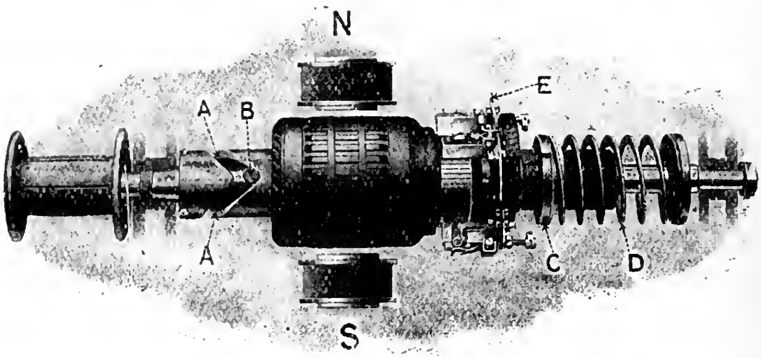


FIG. 6.

The brush gear automatically takes up the correct position, or "lead," by a simple adjusting arrangement. As the armature slides along the shaft, the brush carrier, or rocker, slides with it. The alteration in the "lead" is effected by having a tapered stop on the dynamo frame.

The Ferguson switch gear consists of two solenoid switches, one for the dynamo switch and the other for the lamps, shown in Figs. 7 and 8.

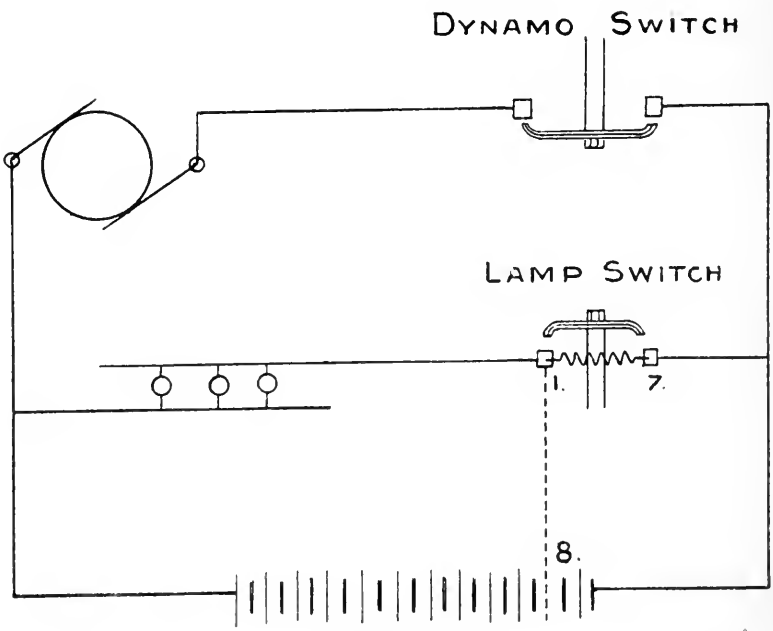


FIG. 7.

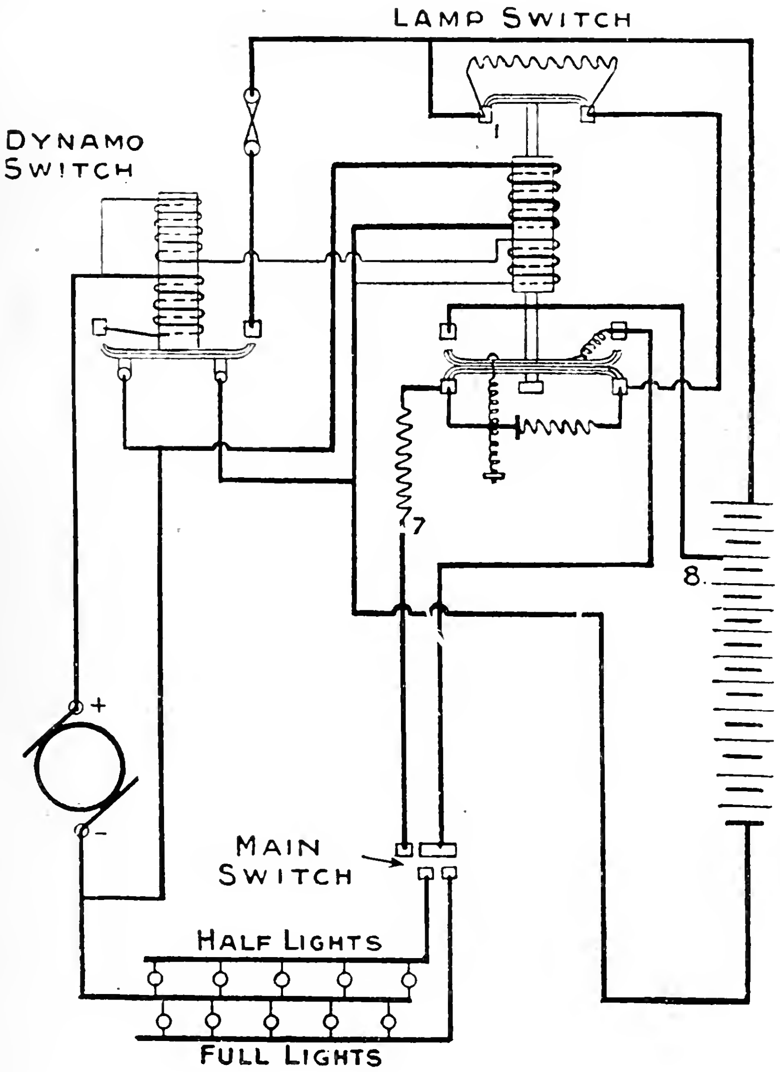


FIG. 8.

The dynamo switch serves to connect and disconnect the dynamo from the battery and lamps when the dynamo voltage (as the case may be) comes up to or falls below the battery pressure. It is of usual pattern, with solenoid having shunt and series winding.

The lamp switch regulates the pressure to the lamps between battery charge and discharge voltage. It is provided with series and shunt windings, the series being only in the battery circuit.

When the dynamo is stopped, the dynamo switch is open and the lamps receive current direct off the battery, the resistance

7-1 (Fig. 7) being bridged over. After the dynamo starts running the dynamo switch closes at the right voltage and the dynamo begins to take over the lamp current. When its voltage rises high enough to charge the battery, then, and only then, is the bridge over the resistance 7-1 removed (in steps) and the balance connector 7-8 established. The lamps are thus connected across 10 cells which are receiving charging voltage. This action takes place between " cut in " speed and dynamo normal speed—say 10 to 12 miles per hour, or 15 to 18 miles per hour. When the normal number of lamps are in circuit no current flows in balance wire 7-8. Switching lamps off only causes the balance of current to flow through 7-8 and does not appreciably alter the voltage on the lamps.

When charging the current flows through the series coil of the lamp switch solenoids, so as to assist the shunt, while a discharge current from the battery to the lamp acts in opposition. Therefore, until the voltage of the dynamo is high enough to supply current to the battery the solenoid remains down, as shown in Figs. 8 and 9. When the dynamo besides feeding the lamps, begins to supply current to charge the battery, the series coil acting with the shunt, lifts the plunger A until the stop comes against the switch bar and inserts a resistance at (1-2).

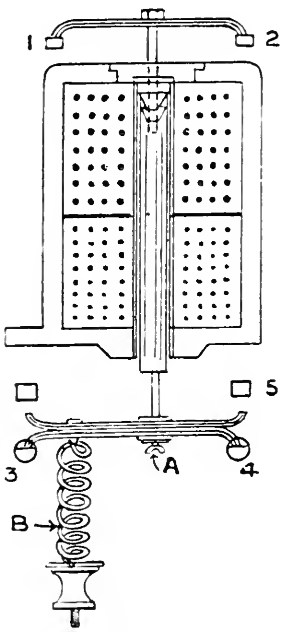


Fig. 9.

When current to the battery becomes stronger the plunger A overcomes the force of the spring B, and owing to the position of the spring will tip up the switch bar across 3 and 5, thus inserting another resistance in series with the first. The leverage is now in favour of the spring, and the last step is therefore not made until the current has increased still more, and the switch bar is then tipped across 6 and 5, inserting the final resistance 3-7 and connecting the lamps across 10 cells.

The Leeds Forge Company supply two sizes of dynamos and switches, viz. :—35 ampere size for ordinary carriages, and 70 ampere size for large carriages requiring extra current, and for block-train lighting.

The 70 ampere dynamo cuts into action at about 450 R.P.M. and runs a a self-regulating machine up to its maximum safe speed, which is 3,000 R.P.M., although the dynamo would regulate beyond this speed. This corresponds to the following

table of speeds with standard 42-inch carriage wheels, and a ratio of 5 to 1 suits all these services.

		Axle Pulley.			
Ratio of Dynamo Pulley	....	4	$4\frac{1}{2}$	5	$5\frac{1}{2}$
Speed Limits in M.P.H.	....	14–94	$12\frac{1}{2}$–83	$11\frac{1}{4}$–75	$10\frac{1}{2}$–68

Newton System.—The Dalziel Constant Voltage Patents, Ltd., have adopted as their standard type of train lighting set a shunt wound dynamo and is a direct coupled differential exciter. The combination is the invention of Mr. F. Newton, of Newton Brothers. The above-named Company previously had a train lighting set which required a regulator consisting of three armatures in one carcase besides the main dynamo, but this new arrangement is much better.

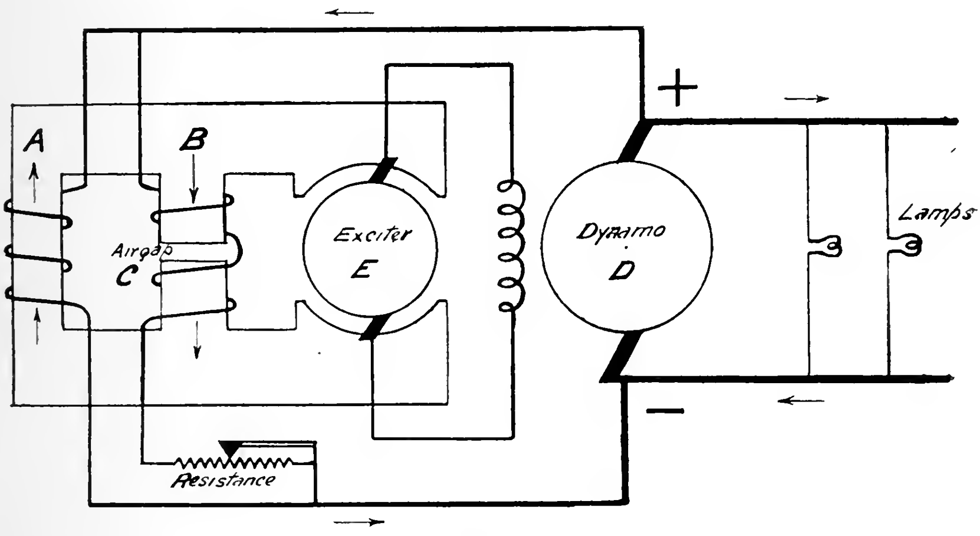


FIG. 10.

Fig. 10 shows the general arrangement of the dynamo. D is the dynamo armature and E the exciter armature. D is excited by field F, which received its current from E exciter armature; the field passing through the exciter armature, being the difference between fluxes in poles A and B. A is a pole of small cross section which is highly saturated. B is a pole of large cross section with an air-gap in C.

Fig. 11 shows the general construction of the whole machine. Both poles are either excited from the dynamo brushes or from the point at which constant voltage is required, so that the magneto motive force of each will vary in direct proportion to the pressure to be controlled.

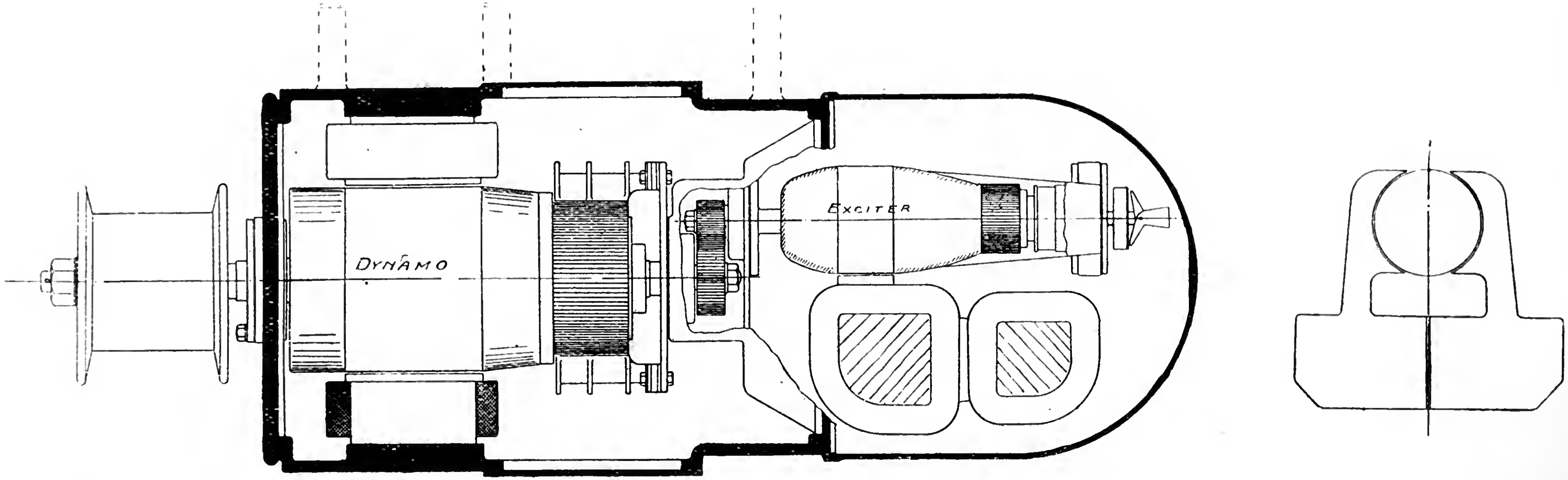


FIG. 11.

The flux in the saturated pole will reach, or tend to reach, its full value when supplied with approximately one tenth of its normal magneto motive force. After this point has been passed the flux will remain practically constant regardless of increase of magneto motive force, because the degree of saturation is very high.

The flux in the pole of large section will vary in almost direct proportion with the magneto motive force, or in other words, with the pressure from which its excitation is derived. The windings on the two poles are such that most of the flux set up in A goes through B, only a small portion going through armature E.

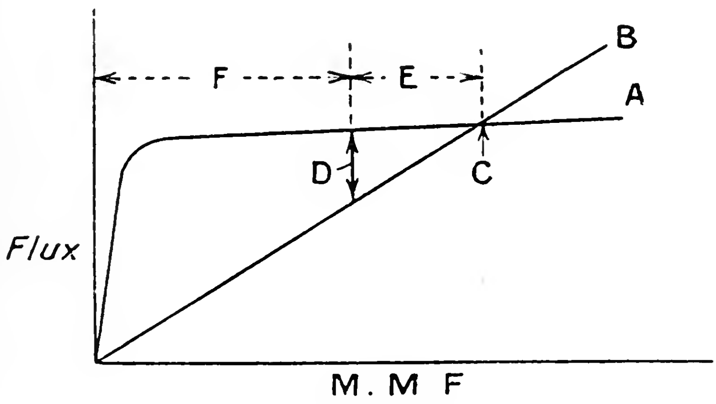


FIG. 12.

Referring to Figs. 10 and 12—

" A " represents flux per magneto motive force in saturated pole.

" B " represents flux per magneto motive force in unsaturated pole.

" C " is the point at which the fluxes in both poles are equal, leaving none for the exciter armature.

" D " represents the amount of flux necessary for the exciter in order to produce sufficient excitation for the main dynamo at its slowest designed or cutting-in speed while giving full load.

" E " measured as a percentage of " F " is the percentage rise in the main volts corresponding to a rise in speed from cutting-in speed to infinity, when no flux is required. The amount E is much exaggerated in order to make the diagram clear.

The field winding F of the main dynamo D is connected directly across the exciter armature E.

It will be seen from the foregoing that only a very small percentage of the flux in the saturated pole is used for the maximum dynamo excitation, the voltage rise is limited to this small amount through a speed range of approximately 450 r.p.m.

(with full load), to an infinite speed with no load. Therefore, the regulation under all working conditions must be very perfect.

The degree of saturation in the saturated pole is such that while the machine is standing the residual flux in the saturated pole, and passing through the exciter armature, is in excess by a large amount of the flux required while the machine is running. This will be clear when the smallness of this latter amount is considered, together with the fact that very little of the residual flux passes through the air-gap of the unsaturated pole. The above being the case, the main dynamo has no alternative but to build up, providing the main shunt circuit remains complete.

The saturation of the exciter field combined with the multiplying effect of the exciter armature, when compared with the similar characteristics of the average commercial dynamo, is many times in favour of this dynamo as regards certainty of building up without assistance. It will be clear that although at very low speeds the flux through the exciter armature is very high, the product of this flux and the speed is definitely limited, and never can be sufficiently great to saturate the main dynamo field circuit. The exciter, therefore, always maintains full control of the building up of the machine.

The dynamo can now be considered with reference to reversal of direction of rotation. When the dynamo comes to rest and is reversed, the residual flux in the exciter field circuit remains in the same direction. The E.M.F. in the exciter armature is therefore reversed. The main dynamo field winding, which as before stated, is connected directly across the exciter armature, is also reversed. The combination of this reversal, and the reversal of rotation, of course, gives a polarity of the main dynamo in the original direction. This is a very important feature, and marks out this system from most of the others. It is a remarkable fact that this machine, when given a turn by hand in either direction, immediately commences to " build up " with a constant polarity.

Figs. 13 and 14 are skeleton diagrams showing the essential connections of this train lighting system. Fig. 13 shows the connections when the train is standing and lights are being run from the accumulator. Fig. 14 shows the connections when the train is running and lights are being run from the dynamo and the battery is being charged.

It is important to note that only one battery is used with this system and also that the battery is quite dispensable as far as regulation goes. Both of these points are of considerable importance, as the use of one battery reduces the cost of upkeep considerably, and the independence of the battery means that should a lug break or any accident happen to the battery, the light is still available while the train is running.

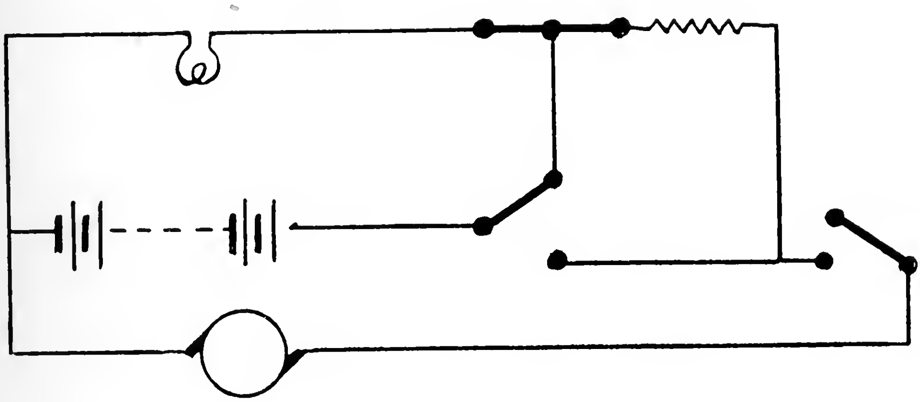


FIG. 13.

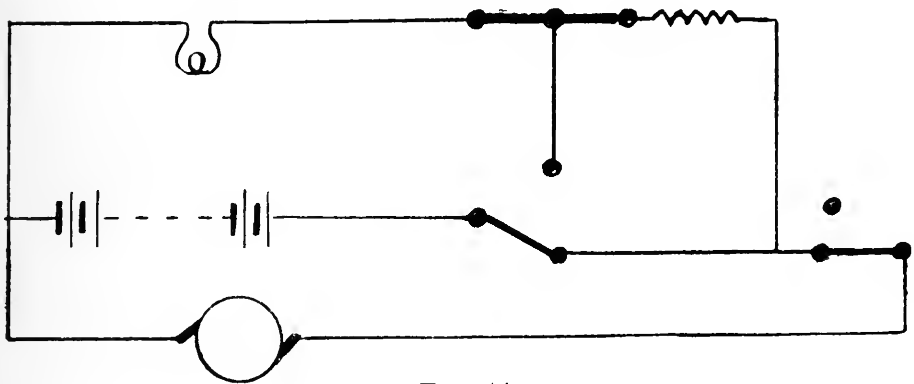


FIG. 14.

Batteries.—From the maintenance point of view the most important item of the equipment is the battery, and some remarks under that head may be of interest. When cells are being charged the specific gravity of the acid gradually rises. As no gas is given off to create circulation it happens that the electrolyte becomes denser at the bottom than at the top. When gassing commences towards the end of the charge the circulation set up by the gas bubbles equalises the specific gravity and for this reason the gassing is distinctly beneficial. During the gassing period any tendency for the plates to sulphate is also checked.

The problem is to charge the cells properly during the first half hour without overloading the dynamo ; or, say without exceeding 50 to 100 per cent. more than its normal amperes. It is usual to provide an accumulator capable of giving the same amperes as the dynamo for three hours.

With a lamp load of 15 amperes and a dynamo capable of an output of 30 amperes at full load, the battery-capacity at the 3-hour rate must be not less than 90 ampere hours. With sufficient pressure to charge the minimum size of battery fully with a constant voltage of 2.32 volts per cell,

the proper size of dynamo according to this rule would actually be overloaded 50 per cent. for half an hour and the dynamo will stand this easily.

To get the best out of a battery, the charging voltage must be higher than 2.5 per cent., which means an excessive rush of current during the first half hour. When to this the lamp load is added, the dynamo may be overloaded more than 100 per cent.

Ideal Conditions of Charging.—The essential conditions for perfect charging of cells are :—To cause the voltage to rise gradually throughout the charge so that there is no rush of current at the start. The voltage rise to be such that there is a steady reduction of the charging current at the tail end of the charge. To ensure such a voltage at the end of the charge that the cells gas freely. To ensure that there shall not be either over charge or over discharge. With stationary batteries and an attendant always about it is fairly easy to ensure these conditions, but for the small batteries on railway coaches and dynamos which are not get-at-able, automatic apparatus must be provided to get as near the ideal conditions as possible. It will be easily seen that the problem is a difficult one and it says much for the skill of the various designers of train lighting plants that they have come so near the ideal.

Life of Battery.—It is a curious fact that a battery floating on a traction load and taking heavy discharges for short periods and corresponding heavy charges, has a healthier life than a battery on a lighting circuit which has a continuous discharge over several hours followed by continuous charge. A train lighting cell has even a better chance than the traction cell, because at every stop or slow down of the train below charging-speed the battery has to discharge for a short time into the lamps. When these alternations follow each other regularly they are good for the cells.

The life of an ordinary lead cell varies from 5 to 10 years, but the latter life is only attained by very careful attention. An annual provision of 10 per cent. per annum on the capital cost of the accumulator will pay for maintenance during life and for renewals of plates and of boxes.

Two batteries are sometimes used so that whilst one battery is being charged, the other is being discharged through the lamps. The two batteries are connected in parallel through a resistance. Unless the lamp load remains nearly constant, this system with a fixed resistance between the charging and discharging batteries is not an efficient regulator. It can be made efficient, however, by automatically regulating the resistance between the two batteries, so as to keep the voltage regulation at the lamps within the prescribed limits.

It will be easily seen, however, that from the efficiency cost, and weight point of view it is preferable to use one battery of twelve cells with a mechanical regulator than two batteries each of twelve cells with a mechanical regulator between them. There is considerably less capital outlay in equipping a carriage with one than with two batteries, also the dead weight to be carried and the cost of upkeep are correspondingly reduced. Storage batteries do not work well when connected in parallel.

Hitherto the lead cell has been used exclusively, but it is very possible that the new alkaline cell having cadmium nickel plates may come into use. This particular form of cell is being very largely employed for electric safety lamps for mines. They not only are able to withstand an astonishing amount of knocking about but they also have great recuperative power. This is shown by the fact that the Wolf Safety Lamp Co. give a 6 years' guarantee with their batteries.

Lamps.—Train lighting has been immensely improved by the introduction of the metal filament lamp. The tungsten lamp requires only $1\frac{1}{4}$ watt, and it has a longer useful life, say, about 900 hours as against 600 hours for the carbon lamp. 900 hours is about equivalent to 12 months' service in this country.

At the usual train lighting voltage of 22 to 24 volts the 10 candle-power tungsten lamp has a filament about 5 inches long and 0.002 inches in diameter.

Regarding the position and number of lamps in a carriage the desiderata are that the light shall be pleasantly distributed so as not to produce the uncomfortable effect of glare and also at the same time the failure of a lamp filament is not inconvenient. This is one of the great advantages of electric light over gas because the smallest candle-power of an inverted burner appears to be twenty.

When a passenger is seated the level of his eyes is about 4 feet from the floor and the illumination at that point should be about 2-foot candles on a horizontal plane.

The writer is of opinion that Tubolite, the sytsem of electric lighting so widely used for shop windows and cornices, is eminently suitable for illuminating railway carriages. It has been applied with excellent effect in the case of the Royal Saloon built for King Edward by the Great Northern Railway Company. The long tubular lamps are held by means of porcelain holders in the position of maximum efficiency relative to a highly polished aluminium reflector. The lamps are placed over the doors of the carriages, and are concealed from view by a projecting moulding. The light is directed upwards on to the white roof of the carriage, and by reflection produce a clear, well diffused light throughout the whole interior. There is no direct glare, and owing to the special design of the lamps and reflector, the

amount of useful light for a given consumption of energy is larger than with ordinary incandescent bulbs. The more general application of this system to train lighting would prove advantageous to the travelling public. They would be economical to the Railway Companies for the lamps do not interfere with the headway and consequently there are fewer breakages, also less current is required for a given amount of light.

Glare is the most important problem in carriage lighting, and it is to prevent it that lamps are placed as high as possible in order to be out of the range of vision. With clerestory roofs they are about 7 feet from the floor.

One way of eliminating glare is to enclose the lamp in a holophane diffusing globe. Such a globe is difficult to clean if allowed to get greasy, and the cleaning must be done with a brush and not with a rag, or better still, the globe may be taken down and washed.

2nd February, 1914.

ORDINARY MEETING.

MR. ARTHUR VALON, PAST-PRESIDENT, IN THE CHAIR.

The Chairman presented the following premiums awarded for papers contributed during 1913 :—

The PRESIDENT'S GOLD MEDAL to Dr. Eric Rideal for his paper on " The Corrosion and Rusting of Iron."

The BESSEMER PREMIUM, value £5 5s., to Mr. Bernard L. Rigden for his paper on " The South Eastern Coalfield."

The CLARKE PREMIUM, value £5 5s., to Mr. Gerald O. Case for his paper on " Accretion at Estuary Harbours on the South Coast of England."

A SOCIETY'S PREMIUM, value £3 3s., to Mr. Wm. Yorath Lewis for his paper on " The Bus *v.* Tram Controversy and other aspects of the London Traffic Problem."

He also expressed the thanks of the Society to the authors of those papers for which premiums had not been awarded, viz. : Messrs. C. A. Battiscombe, Reginald Brown, C. H. Cooper, F. H. Hummel, and Louis S. Spiro.

INDUCTION OF THE PRESIDENT.

Mr. Valon then invested Mr. H. C. H. Shenton, his successor in the presidential chair, with the President's badge of office and presented to him the certificate of his election as President.

Mr. Shenton, on taking the Chair, said that his first duty was to propose a vote of thanks to Mr. Valon, the retiring President. That gentleman had done his duty very splendidly, and had not only been present at the ordinary meetings and the council meetings, but had represented the Society on a large number of occasions, including dinners and other proceedings to which the President of the Society received invitations. An ordinary member of the Society hardly knew what a lot of work the President had to do. Mr. Valon had carried out his work admirably and had been a most excellent President. It would be very difficult for him (Mr. Shenton) to follow in Mr. Valon's footsteps.

Mr. D. B. Butler said that it was his privilege to second the vote of thanks. As a Past President he could fully realise the

amount of work which fell to the lot of the President during his year of office. Representing the Society at various functions, notably dinners, was very often a serious matter. In that respect Mr. Valon had his sympathy. He could confirm what Mr. Shenton had said, and he would ask the meeting to pass a vote of thanks to Mr. Valon for his services during the past year.

The motion was put to the meeting and carried with great heartiness.

Mr. Arthur Valon, in acknowledgment, said that a vote of thanks was always a most difficult thing to speak to. His work as President during the past year had been a pleasure to him. Both the proposer and the seconder of the vote of thanks had referred to the duty which devolved upon the President of attending a large number of functions, particularly dinners. For some time last year he had an average of two a week, and he then thought that probably he should have to take some course of treatment at the end of his year of office if he was to restore his figure to its ordinary and normal state. But his experience was slight compared with that of other functionaries. He had been told on very good authority that one Lord Mayor of London had not dined at home on one single evening during his year of office. He hoped that the President of this Society would never have to face such a state of things as that. He had enjoyed his year of office exceedingly, and the last duty which he had had to perform, that of inducting his successor, had not been the least pleasurable one which he had discharged during the year.

Mr. H. C. H. Shenton, the President for the year 1914, then delivered his

Presidential Address.

It is necessary for me, in the first place, to express my sincere thanks to the Society for electing me as their President for this year, and to state my great appreciation of this kindness and also of the responsibilities which attach to the position.

A Society like our own, which if we consider the age of the two amalgamated Societies, has been in existence for sixty years, and which is open to all engineers, whether civil or mechanical, has evidently a good reason for its existence, and has a great work to do, viz., to consider and promote the welfare of all engineers, irrespective of their exact calling or rank. It is a question whether the growth of a large number of new engineering societies is for the ultimate good of the profession. Indeed, unless they co-operate they must inevitably tend to reduce each other's vigour and consequent usefulness. Greater co-operation and more friendly intercourse is, therefore, very desirable, for

it is perfectly obvious that the energy of each individual is limited, and that, with the multiplication of societies and their meetings, the attendance at each meeting must be less, and that mediocre and indifferent results will be produced unless there is some sort of combination. Friendly intercourse is, therefore, desirable and essential.

The Organisation of the Engineering Profession.

There are many signs that there is need for better organization in the profession. This is to be observed both in England and in America, and a great deal of consideration has been given to the matter, but at the present time many of the efforts made are individual and spasmodic, the work done by the largest body of all—viz., the Institution of Civil Engineers, being in a great measure unknown to the vast body of engineers. Some societies make such work the nominal object of their existence, and incidentally it may be observed that the mere existence of any society of engineers should tend in the direction of proper organization of the profession, for the first rule of that society should be that its members shall be engineers.

Engineering is an honoured profession, and good engineers receive quite as much consideration and respect from the general public as they either desire or deserve. No better organization of the profession will increase the respect with which a properly trained and qualified engineer is regarded at the present time. There is nothing in the profession as it stands which makes it in any way less honourable than the highest professional calling. The trouble is that the general public often regard persons as engineers who have absolutely no claim to the title ; such persons being allowed to call themselves engineers without hindrance.

The Society of Engineers is at the present time devoting considerable attention to the subject referred to, viz., the organization of the profession and the well-being of the engineer, and will spare no pains in the future to promote this object. Such work is being considered, not as an isolated effort in opposition to what is being done in the same direction by other societies and institutions, but is taken up with the object of ultimately securing a combined effort of the whole profession, and the formation of a controlling body representative of every branch of the profession, which would thus be in a position to accomplish effectively the reforms which are generally admitted to be necessary. This is not a selfish undertaking, done simply for our own honour and glory, neither are we arrogating to ourselves a right which belongs equally to other societies, but it is a genuine effort to increase the interest of engineers in a movement to their own advantage and to support loyally any satisfactory effort that may be made by others.

Although there is nothing wrong with engineering as a profession, there are a great many difficulties with which the engineer has to contend, which come under consideration. The employment of persons who are not engineers to do engineering work is one of them ; the employment of engineers at an improper rate of payment is another, to give only two instances. In the legal profession no unqualified person may practice as a solicitor under a penalty, yet in the engineering profession, where human life is sometimes dependent upon the work, no such safeguard is to be found. It is quite a common thing to find an over-worked surveyor in a rural district receiving a salary of perhaps £60 or £70 a year, dealing with the spending of very large sums of money on purely engineering work. If the profession were properly organized, such a person could not be found. If he were competent he would not be allowed to work for insufficient pay, and if he were not an engineer he would not be allowed to do the work.

I would therefore urge that all engineers, whether they are members of this Society or not, should regard the serious effort that is being made for the better organization of the profession, and that they should assist us by bringing matters pertaining to the subject to our notice, and by working in friendly conjunction, and should remember that we, as a Society, are anxious to assist them in anything that can have a useful bearing on the subject.

Waste of Public Money.

Much public money is wasted owing to these causes, and taking only one expense, viz., that of the work done for local authorities by persons who are not engineers, the fact is perfectly plain, and it is therefore necessary, in the public interest, that engineers should combine in the endeavour to make it impossible that their work should be given to persons outside the profession. Again—and here I speak on my own subject—it is equally important that such works as those of sewerage, sewage disposal and water supply should be carried out by engineers who have special knowledge and experience of these particular subjects. At the present time this country is full of instances where the public money has been wasted by the construction of works which are quite unsuitable for their purpose. If the list of failures in sewage disposal works and in water supply works were recorded, together with the names of those responsible for the work done, the result would be very instructive.

Again, this appears to be an age in which any person, without respect to his qualifications, may pose as an authority, and write a text-book for the use of students. There are to hand at the present time examples of recently published books on

engineering matters, and especially upon the subjects of water supply and sewage disposal, which are full of obvious errors. Such books may be useful enough to the engineer of experience who can discriminate between right and wrong, but it is grossly unfair to the student to put into his hands a text-book calculated to to lead him astray. It seems as if all that is required at the present day is for a person to make an assertion. The assertion goes forward, frequently without comment, as a fact, and becomes a source of error. The authority is generally unquestioned. This is an unreasonable attitude on the part of the public, including sometimes engineers. If a great engineer, of world-wide reputation, makes an assertion, that is merely his opinion, but we have it on good authority, and it is therefore of great value ; but if an unknown person of inconsiderable attainments writes a book and makes various hard and fast rules and assertions, these ought not to be allowed to go forward for the guidance of students without proof. It seems as if some sort of press censorship is desirable. A department might be formed for the careful reading of new books written by unknown authors, with a view to their inclusion in a list of text-books suitable for students preparing for examinations. Naturally, when a student visits such a library as that of the Institution of Civil Engineers, he is inclined to regard the books in that library as having received the approval of the Institution, whereas such libraries receive books both good and bad. I have certainly come across books and writings recently which bear traces of the mental aberration of the author, but such books frequently receive no proper criticism in the engineering press and may be accepted as among the number of ordinary text-books.

Again, some of these books are written, if not by manufacturers themselves, by those who appear to be willing to advertise the goods of a special manufacturer. A book upon water supply, for instance, may, under the heading of "Water Purification," speak of a certain make of mechanical filter as if that filter were the only one of its kind, and may entirely omit to mention the large number of other methods which exist for the purification and treatment of water.

Water Supply.

At the present time there are certain definite lines of policy that are observed in connection with water supply, and certain principles have also been accepted which will have a far-reaching effect upon engineering work in the future. These are of various kinds and are the outcome of general experience, research work, the work of the Royal Commissions, and other causes. It has been established within the last few years, and has been definitely

confirmed by the Eighth Report of the Royal Commission on Sewage Disposal, that water authorities must be responsible for purifying waters drawn from a river, while the local authority discharging sewage into a river need only purify that sewage to such a degree as to prevent actual nuisance. Considerable doubt existed not so very long ago as to whether it would not be incumbent upon the local authorities to purify sewage to such a degree that all possibility of disease germs entering the river was removed. There was a feeling that an authority like the Metropolitan Water Board ought to pay part of the cost of the works of local authorities in the Thames and Lea valleys discharging effluents above the Water Board's intakes, and claims were made by local authorities who considered that such assistance should be given them. In particular, the author had some experience with regard to this matter in connection with the works for the Sawbridgeworth Urban District Council, in Hertfordshire; where such a claim was actually made, which became a test case, and where much consideration was given to the matter before it was finally decided that the Metropolitan Water Board should not contribute to the cost of the works.

It is also now generally acknowledged that there is need for the collection throughout the country of data as to sources of supply. A systematic hydrographical survey is required. We need to have fuller particulars with regard to rainfall, the run-off of the land and the yield of streams and rivers. The formation of a Central Authority and of Water Boards is required so that the national supply shall be considered as a whole, and although legislation is slow, there can be no doubt that we shall ultimately obtain what is required, and that eventually the whole matter will be administered much more satisfactorily and economically than is at present the case; for it is obviously very wasteful when one large community, which happens to be divided into two or more districts, is allowed to spend money upon two or more separate schemes, when one large scheme would have met the requirements of the case much more satisfactorily. The combination of districts is to be desired; the appropriation of the sources of supply and gathering grounds by one water authority to the detriment of others is to be deprecated, and the enormous expenditure of money, owing to the conflicting interests that takes place whenever any scheme is brought forward, ought to be avoided. As things stand at present it is generally acknowledged that reform is required.

Economy of Scientific Treatment.

Another even more important point, that has not yet received the general acceptance that it will receive in the future, is the absolute need of water supply problems being placed in every

case in the hands of those who can deal with the matter scientifically, making use of the most recent knowledge and experience on the subject.

It is becoming more and more evident that the engineer must work with the chemist and bacteriologist. To give a few instances ; if the water supply of London had not received this thorough attention, we should long ago have had to abandon our present sources of supply, and enormous expense would have been incurred in bringing water from a source further afield, but owing to the fact that the whole question has received the very best attention, we have a combination of districts, a reduction of waste, a water drawn from sewage polluted rivers rendered fit for drinking purposes, and what would at first sight appear to be quite impossible brought to successful fulfilment. The same thing applies exactly in other cases. For though the smaller works are of less importance—regarded collectively, from a national standpoint, they are of greater importance even than the supply of London. It is not sufficient for the engineer to obtain a supply of water free from disease germs, obvious pollution, discolorization or objectionable mineral constituents. A water which is apparently desirable in every respect may yet cause very serious corrosion in mains, and algal troubles in the reservoirs, may be productive of animal and vegetable growths in the mains, and may clog the filters. The conditions need to be much more carefully considered than has formerly been usual, and in this the engineer needs very considerable assistance from the chemist and bacteriologist. We are well aware that hard water may be softened, and the fact that plumbo-solvent waters may be treated with lime so as to remove this quality is fairly well known, but it is quite a new idea and one that was only recently brought forward in a paper read before this Society by Dr. Eric Rideal, that a water may be treated in such a manner as to provide a protective coating to the interior of an iron main, so that corrosion shall not take place. In a report issued by the Institute of Metals such treatment of water was recommended in connection with boiler tubes, but it did not appear that anyone had suggested that it could be applied satisfactorily in the case of water mains. The protection of the interior of water pipes is not an easy matter, and if it can be effected by the treatment of the water it is clear that there will be a saving of expense, because this treatment would only be required at long intervals of time.

The manufacturers and patentees of various processes act upon scientific advice in many cases, but they are naturally special pleaders for their own particular systems, and as commercial men cannot be expected to give the disinterested advice that is given by the private engineer. Unfortunately it is quite a common thing for work to get into the hands of persons who,

possessing insufficient knowledge, rely entirely upon advice obtained from manufacturers. This is particularly so in the case of water treatment, and it is also true to some extent in the case of other matters such as reinforced concrete, which matters will be again referred to.

It has hitherto been generally taken for granted that if a certain water produces corrosion or clogging of iron mains, that the only cure for the difficulty would be to put in mains which are of such a character that they will not corrode. Thus pipes are coated with preservative solutions, sometimes with Portland cement, metallurgists seek to find a metal which will not corrode, reinforced concrete pipes, wood stave pipes and so forth are suggested, but all recent experience tends to show that it is not so much the pipe which is at fault as the water, and that if the matter is dealt with scientifically the corrosive qualities can be removed. This is but one example of the importance of the question being dealt with as a whole, carefully and separately in each case, by the best scientific advisers, including engineers, chemists and bacteriologists. In cases where underground supplies are in question it goes without saying that the assistance of the geologist is also required.

The Consulting Engineer.

On small works, the work of the engineer specialist, the consulting engineer proper, ought to be very carefully distinguished. It certainly seems that the use of the consulting engineer on such work is not properly understood by his clients. Such an engineer is called in to prepare a scheme and to advise as to the expenditure of a large sum of money to the best advantage. Unless he has considerable knowledge and experience he cannot do such work. It is work of the first importance, and should be highly paid. On the other hand, when the works have been designed, when all the difficulties of the preliminary investigations have been settled, the constructional work does not necessarily require this degree of knowledge. A man of average attainments can look after the laying of a good many miles of water main quite satisfactorily, and supervise the construction of works which have been properly designed and specified. Such work does not deserve payment at the same rate as that of the consulting engineer, but if we look at the facts of the case we see that whereas the consulting engineer is expected to prepare his preliminary report and scheme at a very low fee, that he generally has no difficulty in obtaining a fairly large one, viz., 5 per cent. upon the cost of the constructional works, in carrying them out. Thus, local authorities have adopted the plan of asking a number of engineers to state the fee at which they are willing to prepare

a scheme, and accept the lowest bidder, or at any rate they haggle over the cost of the preparation of the most important part of the work. They refuse to pay the fees of other scientific advisers, and as a consequence the best engineers cannot take up such work, and those who do take up the work have to obtain their fee later, from the commission on the money paid for its construction. The folly of this generally accepted method is so great that it ought to be the work of engineering institutions and societies to educate the public to a better sense of its duties. If a consulting engineer were employed at a proper fee, and it would certainly have to be a large one, to prepare a scheme of water supply, sewerage, or sewage disposal, the actual constructtion of the work might very often be left with advantage to the District Surveyor, under the guidance of the consulting engineer in case of any particular difficulty. To expect a great consulting engineer to be able to give much personal attention to the laying of long lines of small sized water main or pipe sewer, the construction of manholes and such-like, is quite as foolish as expecting a consulting physician to make pills with his own hands. He can, of course, employ competent assistants to do the work, but seeing that the consulting engineer is capable of giving advice upon matters of high importance where his opinion is of the greatest value, he should be properly paid for his legitimate work, and the practice of local authorities in endeavouring to cut down his fees or to eliminate them altogether is wasteful in the extreme. More money must be spent in the future upon obtaining the best possible scientific advice, and this will result in a very great economy in the cost of the works, whereby the money spent on the specialist will be saved many times over.

It is also entirely wrong, especially in the case of smaller works, that the more expensive the scheme the greater should be the fee of the engineer, and that the more personal attention he gives to the scheme the less will be his rate of payment, for it is certainly possible by giving one's best work to devise a scheme which will be very economical. Thus the careless or incompetent person who designs works of an unnecessarily expensive character will receive a much larger fee than the better engineer who works out a thoroughly economical scheme. It is the duty of a Society like our own to take steps to educate public opinion in this matter. It is not to be supposed that such work can be done quickly ; it will undoubtedly take many years, but those who have the welfare of the profession and the general public welfare at heart will see the necessity of working on these lines.

As a striking example of the folly of approaching waterworks problems unscientifically may be instanced the large number of dams which have failed in America and elsewhere.

In most cases these failures have been due to lack of geological knowledge. The dams themselves have been quite strong enough to withstand the water pressure, but the water has managed to find its way underneath them. We have many instances in this country, as well as abroad. of the difficulties which have occurred owing to the particular geological conformation of the ground.

It is wrong to take the view that the engineer can be a specialist in all subjects, and it is perfectly correct, for instance, for the municipal engineer to call in the consultant to advise him or his Council in case of need, in the same way as the Town Clerk will require to have counsel's opinion upon any difficult point of law, and it is also perfectly correct for the consulting engineer to require the advice of other engineer specialists, of chemists, geologists, bacteriologists, and so forth, as the case may require. If the profession is to be properly organized the consulting engineer ought not to undertake personal work for which he does not specialise. It will at once be urged that under such conditions it might be impossible for him to earn a living, but this is not so, for if each man undertook to do only the work for which he was specially fitted, and if other engineers refused to do that work, it stands to reason that he must of necessity receive a great deal more of his proper work and that he would do this with greater advantage to himself and to his clients than could possibly happen in the case of work that rightly belonged to some other engineer. He would have to pass on such work as he was not personally well qualified to do, and for which he has even now to pay away the bulk of his profits to skilled assistants, if he carries it out properly. It is still worse for an engineer to take up work which he does not understand and to obtain advice from manufacturers, who in some cases even go so far as to call themselves consulting engineers.

Advice Given by Manufacturers.

These manufacturing firms employ expert assistants, but they give designs and advice free of charge in order to sell their appliances, and although they, the manufacturers, may receive disinterested advice from the engineers whom they employ they must recoup themselves, and if they, as commercial men, do not give disinterested advice, they cannot be blamed. This is particularly the case with regard to reinforced concrete. Many persons, having a reinforced concrete structure to build, obtain their designs free of charge from the manufacturers of reinforcing material. If they possessed the knowledge required they would design their own structures, and if they cannot do this they ought to consult a specialist and work with him, and pay him for his advice. The Local Government Board have very properly raised

very serious objections to the reinforced concrete designs brought forward by the officers of local authorities when it was perfectly clear that such officers had a very imperfect knowledge of the subject and relied entirely upon advice given by manufacturers.

Similarly, in water purification or sewage disposal there are many instances of persons obtaining direct from manufacturing firms designs which may or may not be the best for the purpose, but which of necessity are designed by the manufacturers in order to sell their particular appliances. If this system of obtaining designs free of charge from manufacturers is to be admitted as being in conformity with the rules of the engineering profession, it follows that any person of organising capacity, however limited his knowledge of engineering may be, may carry out very large works which are really designed by other people, and about which he is quite incompetent to express an opinion, and may charge the full fees of a consulting engineer for doing so. Moreover, the system is most unfair to the manufacturers, who, in order to keep their trade, must prepare a very large number of designs which are never used, without making any charge for them, such designs frequently being required merely for estimating purposes. If the profession recognised its responsibility in such matters, and could educate public opinion in the right direction, there would be a great saving of time and money to the manufacturer, and only the properly qualified engineer would be able to take up work.

It may be urged that these ideas are impracticable, but if we cannot attain our ideals within a lifetime we may yet work towards them. We have not to consider what is easy of accomplishment but what is right.

Recent Developments in Water Engineering.

Of recent developments in water engineering the various methods for the treatment and purification of water are very remarkable. The possibilities seem almost infinite, as if there were no water, however impure, which could not be raised to a high standard of purity by adequate treatment. The growing practice of purifying swimming bath water and using it over and over again for months demonstrates extraordinary possibilities. It has been found that, after many months use, water so treated is quite equal in quality to the ordinary town supply. The use of the mechanical filter, together with chemical treatment, has increased enormously, and there are many instances of the employment of such filters dealing with several million gallons a day, some of them being in this country. There are also many other filters of various types which have their uses according to special conditions, and the slow sand filter is still very largely employed. Sterilization of water by means of hypochlorite has been very

generally adopted in America, and also to some extent in this country, notably as an after treatment with the mechanical filter, and there is abundant evidence to show that the typhoid death-rate has been lowered, and sometimes lowered to zero as the result of this treatment. Ozone sterilization is in use on the Continent at a good many large installations, and the ultra-violet rays have also been applied to the sterilization of comparatively large town supplies in France. It cannot be said that these methods have made much headway in this country, the reason being that our supplies as a rule are not open to the objection of gross pollution. It is, however, notable that Dr. Houston has advised the Metropolitan Water Board to sterilize the flood waters flowing into the storage reservoirs by means of an overdose of lime, and it is also notable that the ordinary lime treatment seems to include sterilization apparently unsuspected hitherto, at any rate in some cases.

Replenishment of Underground Supplies.

A recent Memoir of the Geological Survey, dealing with the wells in the London district, contains the suggestion that the water-bearing stratum, viz., the chalk under London, should be replenished artificially with water, and it is suggested that the water falling upon the impervious stratum surrounding London should be drained into dumb wells, carried down to the level of the Thanet sands. An enormous quantity of water which now runs to waste would thus be collected. This would be stored in the fissures of the chalk and would raise the level of the water throughout the London district, which level has fallen 100 ft. or more within recent times, owing to the enormous amount of water which is pumped therefrom. The advice is based upon Mr. Bryan's experiment at Lea Bridge, where a large quantity of filtered Lea water was run into the wells, with the result that the well supply was materially improved during the drier periods of the year. This is certainly a very interesting suggestion, and the principle probably has many other applications.

The Work of State Departments.

The value of hydrographical surveys and of State consideration of water supplies is shown at present chiefly by the work done abroad. The work in America is well known, while in our own colonies we have such examples as the case of Western Australia, where the State Engineer, having reported a large sub-artesian basin existing under the drier districts, boreholes were sunk throughout the sandy plain, with the result that good supplies were secured at depths of from 20 ft. to 100 ft. The good work was assisted by the Government, who lent the settlers hand-boring plant. Thus great advantages were derived and many

wells and reservoirs were made. It is questionable whether the same degree of praise is to be given to the German Government, who recently sent a water diviner to South Africa "to practise under State patronage the cult of the divining rod."

Pumping.

One of the most important changes in connection with water engineering has been in pumping. The use of the high speed engine, the steam turbine, the internal combustion engine, and the electric motor, has resulted in the development of the rotary pump. Centrifugal pumps are now largely used, and by running in series are found to be efficient and useful for very high lifts. Producer gas is found to give economical results for large and small powers, and its application is very marked. Further, we have the Humphrey explosion pump, which does away entirely with the engine and most of the working parts of the pump, of which the Chingford installation provides an example near to hand. This pump is also being used for sewage lifting, and apparently has an application for both small and large supplies where a moderate lift is required.

Water Waste.

An interesting point relating to some of the older systems supplied from new sources under great pressure, is the effect which a largely increased pressure, has upon the old mains, services, valves and fittings. This is particularly the case with regard to New York, where it is feared that the increased pressure may lead to a considerable loss of water from various causes. It is certainly a point to be borne in mind where a new supply at a higher pressure is provided. In London we have a splendid example of what may be done by careful inspection and scientific management in reducing the loss of water due to waste, but such methods are not by any means universally adopted. In American cities the waste is apparently enormous, and a great deal of interesting work is being done in order to reduce this waste. The pitometer is a simple instrument which has been proved to be exceedingly useful in measuring the flow in water mains, and by its use a great deal of waste has been discovered. Great carelessness is sometimes shown in this country with regard to waste. In one instance within the writer's experience a small town whose population had not increased in any marked degree since the water works were constructed, found it necessary to duplicate its well, reservoir and pumps owing to the insufficiency of the supply. It was clear, however, that enormous waste was taking place, and eventually a 4in. main was discovered at the lowest part of the system broken in half, discharging into the river, but the great point is that this discovery was not made until the works had been duplicated.

Water Mains and Reservoirs.

The use of steel mains is largely on the increase, and although the Local Government Board will sanction only a short period loan for them, they appear to be taking the place of cast iron mains in a great many cases.

With regard to reservoirs, the chief advance is in connection with reinforced concrete, which is undoubtedly a very economical and useful material, and it is evident that a large number of reinforced concrete reservoirs, some of them of large capacity, are being built in this country. In this case again, the Local Government Board will not sanction a loan for a long period, but the saving which accompanies the use of this material is so great in some cases as to do away with the inconvenience that would otherwise be experienced from the repayment of a loan during a short period, that is to say the annual payments are sometimes found to be very little larger in the case of the short loan for the reinforced concrete than for the long period loan with a masonry structure.

One of the most noteworthy features of recent practice is the increased use of cement injection. We see, for instance, in the case of the Catskill Aqueduct, that the tunnels were made of concrete and that these were made watertight by systematically injecting cement grout under pressure behind the walls of the tunnels. There are several instances where extensive fissures causing leakage under reservoir dams have been satisfactorily filled with cement grout forced in under pressure through borings. The same method is sometimes adopted in order to form masses of concrete for foundations where clean gravel exists under water. Some interesting experiments have recently been carried out with regard to this matter. The rendering of surfaces by means of the cement gun, wherewith cement is thrown out under pressure from a nozzle and applied to the surface to be treated, is worthy of note. The method has also been used for lining large pipes.

With regard to the storage reservoirs and the construction of dams, recent progress shows that very much more attention is being given to geological considerations than was formerly the case, and that it is worth while to give very much greater attention to preliminary investigations with regard to the site of the reservoir and to prove by every possible means its suitability before starting the work. Sir Alexander Binnie in his recently published book has laid the greatest stress on this point.

Dr. Houston has shown in the case of London that storage reservoirs may be used for water purification, it being found that a few weeks storage is sufficient to kill or to devitalize harmful germs. The method is hardly likely to be very generally applied, because the water probably does not need such purification,

and moreover, the cost of constructing the reservoirs makes the system prohibitive in the majority of cases. There are also possibilities of trouble with regard to algal growths in the water.

Private Supplies.

One of the most remarkable points that may be noted regarding our present system of water supply in this country is the manner in which, in the middle of a water district, the private individual is at liberty to make his own well and obtain his own private supply. The fact that in London there are a very large and increasing number of wells supplying works, institutions, offices and the like, in the middle of the district of the Metropolitan Water Board, suggests that there is something amiss. It seems as if there is a waste of energy in this duplication of works, and while the private owner relies upon the public mains for the protection of his building in case of fire, he appears to be exempt from his responsibility of paying for it if he has his own private wells. Interesting as all these private supplies may be, there seems to be something amiss in the general control of affairs that they should be necessary.

Sewerage and Sewage Disposal.

With regard to sewerage and sewage disposal, we are in a much more satisfactory condition than was the case only a few years ago. The first Reports of the Royal Commission on Sewage Disposal were certainly open to criticism, but there is no doubt that their work has been an education to the officers of the Commission, and consequently the later reports have been of much greater value, and have removed many misconceptions. It has been found that there are a number of methods of sewage disposal, none of which is applicable to all conditions, but which have each their special uses. Sewage can be certainly purified to any required degree, and the Fifth Report of the Royal Commission dealt very fully with the various possibilities. However, the existing conditions throughout the country still gave rise to very great dissatisfaction. It was seen that purification works were demanded for various towns regardless of the local conditions. There were instances such as that of Erith, where an effluent of a high standard of purity was made to discharge just below and within sight of the Barking and Crossness Metropolitan outfalls, where sewage of very much greater volume is discharged in a very impure condition. Practically no attention was paid to the question of whether a nuisance was caused by the discharge of sewage or not. The publication of the Eighth Report of the Royal Commission, however, shows that this matter has received considerable attention. The officers of

the Commission, as will be seen in the appendix to the Eighth Report, suggested that the quality of the sewage discharged was not the chief matter to be considered, but that the stream itself ought to be the ultimate arbiter in the case. Thus, if a stream or river, after the discharge of sewage or effluent into it, were found to be unharmed, that is to say if it showed no signs of nuisance, and if it retained a certain degree of dissolved oxygen, this should be taken as proof that the sewage required no further treatment. Further, experiments carried out with great care showed that if sufficient dilution were given to screened sewage entering a river, purification was effected by this dilution. The Commissioners did not actually adopt this suggestion made by their officers, but advised that the law should be altered, so that a person discharging sewage into a stream should not be deemed to have committed an offence, provided that the sewage conformed to a certain standard. They suggested for this general standard that the sewage discharged should not contain more than 3 parts per 100,000 of suspended matter, and with its suspended matters included should not take up at 65° F. more than 2 parts per 100,000 of dissolved oxygen in 5 days, but they also advised that special standards, demanding either a higher or a lower degree of purity, should be made applicable as local circumstances might require or permit. Thus if the dilution afforded by the stream were very low, the standard would have to be raised, but if the dilution were very great the standard might be relaxed or suspended altogether, and that if the dilution should be over 500 volumes, all tests might be dispensed with, and crude sewage, from which the solids had been removed, might be discharged. These are most important recommendations, and will no doubt be acted upon at some time in the future. It must not be thought that there is any probability of persons or authorities being allowed to discharge unscreened crude sewage into rivers which serve as sources of water supply, though it is quite conceivable that in some cases where the dilution is sufficient, filters may be omitted.

Bacterial Pollution of Rivers.

Experiments in the Great Lakes of America have shown that harmful bacteria from sewage may be carried out for several miles from the shore and may contaminate water at intakes situated in places which one would imagine to be in absolutely safe positions. The Royal Commissioners do not say anything about the possibilities of bacterial pollution in their Eighth Report, but it is probable that in the case of the American outfalls the reason why harmful bacteria are carried to such great distances in the water is because the sewage is unscreened. For it is certain that with floating solid matters there is no limit to the

distance to which disease germs may be carried, and this may account for the many serious typhoid epidemics in America, while we in London, drinking water which is admittedly sewage-polluted, apparently suffer no ill effects, and typhoid germs are not found even in the raw waters. If even a small proportion of the sewage passing into the Thames and Lea were unscreened, there is very little doubt that conditions would be very different.

Stand-by Tanks.

One of the most useful recommendations contained in the Fifth Report of the Royal Commission was that referring to the use of stand-by tanks for storm-water at the disposal works. In the older works filters were generally designed to deal with a certain volume flowing down at a certain rate, and every time this rate of flow was exceeded the sewage escaped over the storm overflow. Now all such sudden rushes are dealt with partly on the filters and any excess is intercepted in the stand-by tanks for further treatment.

General Purification.

The usual principle at the present time is that of keeping back the sludge by screening, settlement or precipitation assisted by the use of chemicals, so that an effluent containing as little suspended matter as possible has to be treated by the filters. The treatment of this liquid is a matter which has been brought to perfection. It can be filtered and treated till it conforms to any required standard of purity, the degree of purity being limited only by the degree of treatment given. If, owing to exceptional conditions, it is necessary to sterilize the effluent, this can be done without any great trouble, as is practically demonstrated by various works where it has been adopted. It may be added that, although when the sterilization of sewage was first suggested the idea was ridiculed, the process is now among generally accepted methods, although it is very rarely that there is any need to apply this process. It has been found possible to construct filters of various types in such a manner that they do not clog up. The black earthy matter that forms in a well-designed filter which has been properly worked, is discharged with the effluent, and can be intercepted in settling or humus tanks, which tanks, if properly designed, are very effective in clarifying the liquid. Indeed, it is to be noted that in the case of Hertford, where it was proposed to use sand filters for the final purification of the effluent, the Metropolitan Water Board, who were the party chiefly concerned in the matter, and the Local Government Board, decided that it would be better to use humus tanks instead of sand filters.

Slate Beds and Contact Beds.

The value of the Dibdin slate bed has been proved, as may be seen in the Seventh Report of the Royal Commission on Sewage Disposal. It is there shown that such beds dealing with crude sewage will, if properly worked, retain their original capacity for an indefinite period, provided that the sludge is regularly and carefully run off. The slate bed thus answers the purpose of the settling tank, but it does more, for putting aside the question of the reduction of the sludge in volume, it is found that the slate bed sludge "possesses only a slight odour," and this statement is quoted from the Royal Commission Report. It is much to be regretted that, owing to the simplicity of the principle upon which they work, the slate bed and the contact bed have very often—one might almost say generally—been badly constructed and improperly worked. Thus bad results have been produced and discredit has been thrown upon a system which should be of very great value to the engineer. The author having constructed many contact beds in different parts of the country, and carried out a considerable number of experiments, both in working and construction, during the last ten years, has found that with proper working contact beds will give excellent results, and are specially useful for the treatment of sewage containing a large proportion of brewery refuse. Further, it is possible to fill the beds in such a manner that no crude sewage or effluent likely to cause a smell is exposed to the air, and thus one of the chief troubles of the sprinkler filter is overcome. It is not suggested that contact beds are better or more economical in construction than sprinkler filters, but it is suggested that under many conditions, especially at small works, they will be found to give very much more satisfactory results. This presupposes that the same amount of care as is generally given to the construction and working of the filter is given to the contact bed. The nuisance from smell experienced with the sprinkler filter is in the majority of cases not very great, and as a rule, freedom from smell may be attained by careful preliminary treatment.

Tanks.

It would seem that, having regard to the recommendations contained in the Eighth Report of the Royal Commission, the settlement of sewage and various methods for the elimination of sludge will receive even more consideration in the future than they have done in the past, and that filtration may not always be required. Tanks of many kinds are in use, such as the septic tank, the continuous flow sedimentation tank, the quiescent sedimentation tank, chemical precipitation tanks, the hydrolytic tank and a large number of others too numerous to mention,

and it seems probable that, in the future, tanks of the Imhoff type will be largely used. In this type of tank the object is to allow the fresh liquid sewage to pass through rapidly so as to avoid septic action, while the solid matters are retained and held in a separate chamber where they remain for some time, being drawn off, without emptying the tank, at convenient intervals. It is found that the sludge, after retention in such a tank for a certain time, loses much of its offensive character and is thus comparatively inoffensive when it is drawn off, but here again the whole process is dependent upon careful management.

The Sewage Works Manager.

The calling of Sewage Works Manager is one of growing importance. The Association of Managers of Sewage Disposal Works is doing excellent work in bringing together a number of men of superior knowledge and experience whose practical work is of such a character that they have earned the highest respect of the engineers whose works are put in their charge, and of all others who have to do with the question. It cannot be urged too strongly that the whole success of sewage disposal works depends upon the employment of the right men to look after them.

Sludge Treatment.

Several processes are in use for the treatment of sludge, and great attention is being given to the matter. Dr. Bostock Hill and Mr. J. D. Watson, of Birmingham, have each recently dealt very fully with the subject in Presidential Addresses delivered respectively before the Association of Managers of Sewage Disposal Works and the Institute of Sanitary Engineers. Owing to the pressing need for fertilisers on the one hand, and to the sludge nuisance on the other, there is a growing feeling that the hopes of the idealist may yet be realised, and that this matter, which is now a waste product, a nuisance and an expense, may become a source of income to local authorities.

Sewage Lifting.

The lifting of sewage is also a matter in which considerable interest is displayed. The centrifugal pump has been improved to such a degree that it will lift even large blocks of stone. Naturally, the efficiency is not very great under such circumstances, but attention is drawn to the matter in order to show that there is every reason for the growing practice of employing centrifugal pumps for sewage lifting. The use of the small electrically driven centrifugal pump is also noticeable in isolated positions where it performs the work of an ejector, being automatically controlled. This electrical arrangement has been much improved and it is rather remarkable that so little is heard of it, having regard

to the remarkable activity upon the part of manufacturers of sewage ejectors. The Automatic Sewage Lift is, under the right conditions, by far the most economical appliance in use.

The Parsons Stereophagus Pump, a centrifugal pump designed especially for sewage lifting, is also worthy of note.

Sewer Ventilation.

The Report of the Local Government Board on the Intercepting Trap tended to demonstrate the comparative harmlessness of sewer gas in general. If the teachings of this Report, which have been much criticised, are accepted, it appears that very little more is required in the ordinary system of sewers than to arrange that there may be no pressure of gas in the sewer, which, as a matter of fact, is really all that is done as a rule in any ordinary town system. It does not justify any relaxation in the efforts made to ventilate sewers, but it is some consolation to be told that the dangers of an ill-ventilated sewer are not so great from a health point of view as was generally believed. The suggested abolition of the intercepting trap is an accomplished fact in some places which seem none the worse for the change. Whether the principle is of universal application is another matter.

Effect of Traffic.

The altered conditions of road traffic and the enormous loads which now come upon road surfaces and upon manhole covers in particular should be taken into careful consideration by engineers. There is increasing need for soundness of construction of sewers and manholes and for strength in manhole covers.

Mr. J. W. Wilson said that the honour devolved upon him as Senior Past-President, of moving a vote of thanks to Mr. Shenton for his Presidential Address. This was the fortieth address of the Society which he had heard, and it certainly compared very favourably with those that had gone before. He was sure that they would all gain much benefit from its re-perusal when it appeared in the Transactions. It was not customary for a presidential address to be discussed like an ordinary paper, which he sometimes regretted. He was sure however, that they must all agree with what the President had said about consulting engineers, the advice given by manufacturers, and many other matters. They must also value the experience that Mr. Shenton had given them from his own practice and the very valuable conclusions that he had arrived at. He was thankful to him for having touched upon the question of the multiplicity of text-books, some of which were admirable and some of which

were otherwise. The young engineer deserved much sympathy from that point of view, even more than his predecessors. The contents of text-books were sometimes extraordinary. Probably some of the members had heard of the professor who asked a friend, " What do you think of my new text-book ? " The reply was, " Well, I admire it very much, but I do not think that I quite understand it." The professor said, " Well, of course, there are only about half a dozen people in the world who can understand it." That was the kind of book which young engineers, at any rate, did not want. Not very long ago he had a letter from abroad which said, " Dear Sir ; If you will introduce the accompanying little book to your students and will get them to learn it by heart from beginning to end, they will be able to pass any examination and will all become good engineers." It was necessary to guard against ideas of that sort. It was evident that the rising engineer under the best circumstances had to learn a great deal more than his predecessors, and if only the way could be made clear to him it would be a great advantage.

The President had once or twice remarked upon the great advantage of careful management. That would apply to almost any aspect of engineering. For instance, in the case of reinforced concrete the designs might be of the finest character, and the theory perfectly worked out, but, unless the actual construction was thoroughly looked after, it was very likely that the result would be a failure. Perhaps some one in the room would take the hint which the President had thrown out, and write a paper giving an account of failures of different kinds, either with or without names. Failures were, perhaps, the most instructive things with which an engineer had to do, but they did not hear quite so much about them as some of them would like.

He was sure that they had all listened with great interest to the presidential address. It had been his privilege to know the President during the whole of his career, and he worthily occupied the position which he had now attained. This was not his first experience as a President ; and he brought to his present position not only great ability, but a personal charm which they all appreciated : he was a hard-working man, and he would make his presidential year a success. The members could do a great deal to help him. They could come to the meetings in large numbers to hear the papers that were read and to show their appreciation of the labours of the authors. They could induce their friends to come to the meetings and visits to works ; and, perhaps, ultimately to become members of the Society.

Allusion had been made to the Lord Mayor dining out nearly every evening during his year of office. He was sure that the President would never dine at home on any evening when there

was to be any meeting connected with the Society of Engineers, and if individual members would do their part as thoroughly, the President would have what they all wished him, a successful year of office. The Society would increase still more in usefulness, and Mr. Shenton would be able to say at the close of the year, as Mr. Valon had already said, that his year had been an enjoyable one, and he would be able to look back upon it in after years as one of the most pleasant experiences in the whole of his career.

Mr. Percy Griffith seconded the motion. He did not think that it was necessary to say much to supplement what Mr. Wilson had said, for he felt sure that everyone present fully appreciated the excellence of the address. He could not, however, refuse the opportunity which fell to him, as the senior Vice-President available on that occasion, of saying a few words of a congratulatory nature with regard to the address. As he had a distant prospect of occupying the presidential chair in the course of the next three years, when he would be looking back at the addresses of his predecessors to see how far they had forestalled him, he was afraid he would have to criticize Mr. Shenton for having exhausted his own subject, viz., water supply, and he only hoped that during the next three years something would happen both in connection with the Society and in regard to problems of water engineering which would give him something new to say. At the present time, he feared that the subject of water engineering was a little bit dry because the President had pumped it out.

The President had referred to the consulting engineer and, in connection with the question of his remuneration, had used the expression " proper fee." They all knew what this expression meant and would have liked to cheer the President as he read that part of his address. He naturally thought the President had started his year well by expressing such views.

Mr. Shenton had taken the opportunity which was offered to an incoming President of supplementing the report of the Council and, in regard to the delicate question of the status of the profession he had revealed to the meeting something of the intentions of the Council.

In seconding the vote of thanks he would ask the members to second the work of the President and of the Council in the directions indicated in the address. It was surely time that the engineering profession, honourable as it certainly was, should be in a position to organise itself in its own interest. The work of the engineer was work done in the public interest, and, while they naturally asked for fees and, as the President had said, high fees, they could only ask for them on the condition that they rendered proportionate services. Adequate remuneration for good engineering work was what they were entitled to plead for,

and he felt strongly that the maintenance of the standard of their work must be guaranteed before they asked for high fees. He would ask the meeting to support the vote of thanks, not only on account of the President's personality, but also on account of the work he had announced his intention of carrying on with the help of the Council. The terms of the address made him very confident that he would carry on successfully the very useful work he had undertaken.

The motion of thanks was put to the meeting by the mover and carried unanimously.

The President : Gentlemen, I must express my very sincere appreciation and thanks for the extremely kind way in which you have passed this vote of thanks. I do not think that it is necessary for me to say more now, unless it is to repeat what Mr. Griffith has said, viz.—that, if any of you can support our work in trying to secure a combined effort of the whole profession in order to accomplish effectively the reforms which are generally admitted to be necessary, we shall be grateful.

20th February, 1914.

THE PLANNING OF A SEWERAGE SCHEME.

A Lecture delivered by Henry C. Adams, Assoc.M.Inst.C.E., M.I.Mech.E. (Member of Council), before the Birmingham University Engineering Society (affiliated to the Society of Engineers, Incorporated).

In addressing you to-night I feel I must first of all express the regret which our late President, Mr. Arthur Valon, felt at being unable to come down and meet you personally last year, when this lecture was first mooted ; and in the next place I must congratulate you upon the excellent suggestion you made to the Council of the Society of Engineers, that one of their number should deliver a special lecture to you upon some practical engineering topic. I trust I shall not be charged with divulging cabinet secrets when I tell you that your suggestion received immediate and unanimous approval. The Council is desirous at all times of promoting or acceding to any movement that has for its object the advancement of the profession to which we all have the honour to belong, or that will increase the utility of the Society, and strengthen the bonds which link the parent body and the affiliated societies together. Although as a Society, we have the advantage of that experience which age alone will give, the two constituent bodies comprising the present Society of Engineers having been founded nearly sixty years ago, we are not wedded to hoary precedents and a rigid conservatism, but on the contrary are ever seeking to keep the Society in the foreground of progress, and make it a real live up-to-date professional association. The improvement of the status of engineers is a matter of the utmost importance and our Society has a permanent Committee, not only to consider the subject upon general lines, but to investigate any allegations of improper treatment of engineers and breaches or professional etiquette.

This brings me to a consideration of the function of an engineering society, and the relationship of its members. The objects of every society are set forth in a formal statement in its Articles of Association, but the most obvious work of any society such as ours, consists first in the dissemination of professional knowledge by means of the papers read at the meetings and the discussions which arise upon them, secondly the extension of professional experience by the inspection of works in progress or completed, and lastly, but by no means least, the fostering of a spirit of comradeship between those upon whose life work depend the safety, health, and welfare of the general public. There are

other spheres of activity no less important, but I will not detain you by referring to them now.

Doubtless the thought has occurred to you, as it has to many others before, what is the use of belonging to a society at all? Well, first of all, membership of the Institution of Civil Engineers is now recognised as the hall-mark of a trained engineer in whatever branch of the science he may have qualified, and it is essential at the present time for every engineer to belong to that body, and the earlier one joins the better the prospect of advancement through the several grades. Membership of some other societies also confers a certain status, and the Society of Engineers, which is cosmopolitan in character, and in fact is the only Society besides the Institution which includes men in every branch of the profession, should appeal most strongly to engineers in their young days when specialisation is a mistake. To achieve success it is first necessary to build a broad foundation, and let specialisation come with more mature years.

The science of engineering is divided into two main classes of work—research, and the application of research. Without research but little progress would be made in materials and methods of construction. If, however, the knowledge gained by research or the experience gained in its application is kept secret, of what advantage is it to mankind? Fortunately for all of us the natural instinct of an engineer is to impart his knowledge to his fellow workers, and this is readily done by means of the various professional societies. If it were not for the societies much of that information would be lost. The papers read before our own Society by men of long experience in their particular branch of the profession, are criticised and discussed by others whose names are household words in the engineering world. The valuable work done by you in your University is well-known to the Council, and they would, I am sure, welcome any original communication that might be made by any of you, either for reading at an ordinary meeting or for publication in the Journal. There is no other or better way of spreading knowledge than by means of the Transactions, and although perhaps this publication is the only tangible result of membership to those who reside in the provinces, it is a valuable asset. The question is a wider one than that. Living as I do in the centre of the engineering world I find invitations and notices to attend meetings of various societies on every night of the week, when someone or other is giving to the world the benefit of his experience, and on some nights there are two or more meetings. The utility, and indeed the necessity, of the Societies is shown by the quality and number of the papers that are read. The importance and success of any society depends upon the number of its members; but without the financial contributions of these members it could not exist

and the profession would suffer by the closing of its doors. Fortunately, or unfortunately, for myself I can claim membership of many societies and although they make heavy demands upon my time I would not withdraw, except for the gravest reasons, because I feel so strongly that the weakening of a society by the loss of even one member, no matter how unimportant the individual may be, is striking a blow which tends to retard the advancement of the profession, which it is our duty and our interest to support, and upon the eminence of which our future welfare so greatly depends. I am afraid I have tarried rather too long on this subject, but it is one in which I am keenly interested.

After selecting the title of my lecture I debated at some length the manner in which I should treat it. You are all doubtless well acquainted with the subject of sewerage and sewage disposal from the theoretical point of view, so I decided to confine myself to practical design. I might have described to you in detail the planning of one or more particular schemes, but the objection to such a course is that designs which may be eminently desirable in one scheme are quite unsuitable in another; in fact of all the schemes that I have been called upon to design I do not think there are any two which are at all similar, even the minor details, which it would be desirable to standardise if possible, varying in each case. The reason is that engineering is not one of the exact sciences. It demands origination, and when origination is unnecessary and duplication commences, the work ceases to be entitled to be described as engineering. I propose, therefore, to consider the subject from the point of view of a man who visits an unsewered town for the purpose of preparing a sewerage scheme, and to trace the investigations he makes and the thoughts that pass through his mind in the evolution of the scheme. As a definite basis is necessary I have brought the drawings of a small scheme which is now before the Local Government Board. The scheme is by no means a model one. There are many features in it I should like to be absent, but I believe it to be the best solution of a very difficult problem. I have selected a small scheme because the problems are simpler and lend themselves more readily to explanation in the short time at my disposal than would be the case in a larger scheme. I will subsequently deal with the remodelling of an existing scheme. If money were no object, ideal schemes could always be adopted, but to be a successful engineer it is of the utmost importance that one should have a well-developed commercial instinct, and it is useless designing schemes, the cost of which, if carried out, would be ruinous to the ratepayers and prevent any other improvements being carried out in the district for many years to come.

(*Mr. Adams then explained the details of the Scheme with which he was dealing specifically.*)

THE SOCIETY OF ENGINEERS (INCORPORATED).

BALANCE SHEET, 31st December, 1913.

Year ended 31st Dec., 1912. £ s. d.	Liabilities.	£ s. d.	£ s. d.
152 4 1	*Sundry Creditors*		168 14 9
39 19 7	*Subscriptions in advance* ...		24 3 6
	Life Membership Account—		
84 17 7	As per last Balance Sheet ...		84 17 7
	Society's Premium Account—		
	As per last Balance Sheet ...	21 4 2	
	Add President's Donation ...	10 10 0	
		31 14 2	
	Deduct Cost of Premiums ...	7 8 9	
21 4 2			24 5 5
	Clarke Premium Account—		
	As per last Balance Sheet ...	15 15 0	
	Deduct Cost of Premium ...	5 16 9	
15 15 0			9 18 3
	Status Prize Account—		
8 8 0	As per last Balance Sheet ...		8 8 0
	Benevolent Fund Account—		
	As per last Balance Sheet ...	56 19 11	
	Add Interest at 4 per cent. ...	2 5 7	
56 19 11			59 5 6
	Accumulated Fund Account—		
	As per last Balance Sheet ...	807 11 3	
	Deduct amount required to increase the Reserve for depreciation of Investments from £39 15s. 4d. to £80 ...	40 4 8	
		767 6 7	
	Add Excess of Income over Expenditure for the year ...	9 13 1	
807 11 3			776 19 8

Year ended 31st. Dec., 1912. £ s. d.	Assets.	£ s. d.	£ s. d.
	Cash—		
190 2 11	At Bank, Current Account ...	217 7 2	
	Do. Deposit Account ...	100 0 0	
8 1 10	In hands of Secretary ...	4 2 1	
			321 9 3
	Sundry Debtors		
81 13 0	Subscriptions in arrear ...	10 11 0	
2 2 0	Admission Fees in arrear ...		
26 9 8	Advertisements in Journal ...	12 6 0	
			22 17 0
	Investments—		
	£606 London and N. W. Rly., 3 per cent. Deb. Stock at 86½ as per last BalanceSheet ...	524 19 0	
	£300 India 3½ per cent. Stock at Cost, as per last Balance Sheet	278 13 6	
		803 12 6	
	Less Reserve for Depreciation	80 0 0	
763 17 2			723 12 6
	(The market value of these Securities at 31st December, 1913, was £721 12s. 5d.)		
	Office Furniture—		
	As per last Balance Sheet ...	34 18 4	
	Less Depreciation at 10 per cent.	3 9 10	
34 18 4			31 8 6
	Library—		
	As per last Balance Sheet ...	45 5 0	
	Less Depreciation at 20 per cent.	9 1 0	
45 5 0			36 4 0

1912 £ s. d.	Liabilities	£ s. d.	£ s. d.
	Bessemer Trust Account—		
	As per last Balance Sheet ...	159 12 0	
	Add Income from N. E. Rly., Deb. Stock	5 4 6	
		164 16 6	
	Deduct Cost of Premium ...	4 9 0	
159 12 0			160 7 6
	Nursey Memorial Account—		
	As per last Balance Sheet ...	44 16 3	
	Add Income from Hammersmith and City Railway ...	1 14 2	
44 16 3			46 10 5
	J. Bernay's Legacy Account—		
	As per last Balance Sheet ...	27 12 3	
	Add Income from L. and S. W. Junction Railway	0 17 5	
		28 9 8	
	Deduct Cost of Premium ...	2 2 0	
27 12 3			26 7 8
£1,419 0 1			£1,389 18 3

1912 £ s. d.	Assets	£ s. d.	£ s. d.
	Stocks on Hand—		
	Transactions and Journals ...	36 0 0	
	Law Lectures	2 7 6	
		38 7 6	
	Less 20 per cent.	7 13 6	
42 17 2			30 14 0
	Bessemer Trust Fund—		
154 9 6	£185 North Eastern Rly., 3 per cent. Deb. Stock as per last Balance Sheet ... ... (Market value 31st Dec., 1913, £136 18s.)		154 9 6
	Nursey Memorial Fund—		
46 7 3	£33 Hammersmith and City Railway Consolidated Ordinary Stock as per last Balance Sheet		46 7 3
	J. Bernay's Legacy—		
22 16 3	£13 L. and S. W. Junction Railway Stock as per last Balance Sheet ... ... (Market value 31st Dec., 1913, £22 2s.)		22 16 3
£1,419 0 1			£1,389 18 3

We have examined the above Balance Sheet and Income and Expenditure Account, and have obtained all the information and explanations we have required. In our opinion the Balance Sheet is properly drawn up so as to exhibit a true and correct view of the state of the Society's affairs, according to the best of our information and the explanations given us, and as shown by the Books of the Society.

3, Raymond Buildings,
Gray's Inn, London, W.
12th February, 1914

(Signed) BEGBIE, ROBINSON & COX,
Chartered Accountants.

THE SOCIETY OF ENGINEERS (INCORPORATED).

INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31ST DECEMBER, 1913.

Year ended 31st Dec., 1912. £ s. d.	Expenditure.	£ s. d.	£ s. d.
	To Printing Transactions	150 7 9	
	Less Sales and Advertisements	60 15 9	
105 2 1			89 12 0
	,, *Administration Expenses*—		
300 0 0	Salary of Secretary	300 0 0	
85 0 0	Rent of Offices	85 0 0	
17 6 8	Fuel, Lighting, & Office Cleaning	17 19 0	
	Postage, Telegrams, Carriage,		
82 17 10	and General Expenses ...	77 0 4	
83 0 7	Stationery and General Printing	59 18 0	
10 10 0	Audit Fee	10 10 0	
			550 7 4
	,, *Meeting Expenses*—		
19 19 0	Hire of Rooms	19 19 0	
18 7 6	Reporting Meetings	18 7 6	
	Refreshments for members at		
4 19 0	Ordinary Meetings	5 15 7	
0 11 0			44 2 1
	,, *Employment Bureau*—		
	County Council Fee	1 1 2	
	Less Deposits forfeited ...	0 5 0	
			0 16 2
24 7 7	,, Smoking Concert Balance ...		22 7 9
9 1 0	,, Law Charges		7 15 11
3 17 7	,, Depreciation of Office Furniture		3 9 10
—	,, Depreciation of Library		9 1 0
—	,, Interest on Benevolent Fund ...		2 5 7
—	,, Balance, being Excess of Income over Expenditure for the year		9 13 1
£764 19 10			£739 10 9

Year ended 31st Dec., 1912. £ s. d.	Income.	£ s. d.	£ s. d.
705 4 5	By Subscriptions for the year ...		686 1 7
24 13 6	,, Admission Fees		22 11 6
3 12 0	,, Interest on Deposit		2 13 0
	Interest on Investments—		
	London and North Western		
	Rly., 3 per cent Deb. Stock	17 2 4	
	India 3½ per cent. Stock ...	9 17 8	
22 1 2			27 0 0
3 18 1	,, Law Lectures Balance		1 4 8
	,, Balance, being Excess of Expendi-		
5 10 8	ture over Income for the year...		—
£764 19 10			£739 10 9

March 2nd, 1914.

H. C. H. SHENTON, PRESIDENT, IN THE CHAIR.

ESPERANTO: AN INTERNATIONAL LANGUAGE FOR ENGINEERS.

By T. J. GUERITTE, B.Sc, M.Soc.C.E. (France).

[MEMBER.]

While literary societies may well be left to debate on languages in general, the claims of an international and auxiliary language such as "Esperanto" may appropriately be discussed by a technical body like ours. The establishment of a standard auxiliary language, to be used as a means of intercommunication between engineers, scientists and technicians of all nationalities, throughout the world, is a question of the same order as the standardization of algebraic notation, of units, and of scientific terminology.

It seems hardly necessary to recall the importance of the work of the Engineering Standards Committee, while in the matter of standard notation for engineering formulæ, much useful work has been done, in the past, by the Civil and Mechanical Engineers' Society, and other bodies. The question, as a whole, is still engaging the attention of the Society of Engineers, and it seems appropriate, therefore, that we should study one of its aspects which hitherto has not been considered by the Society.

In approaching the subject we are at once confronted with two important questions :—

1. Would there be, from the point of view of scientists and technicians, any advantages to be derived from the universal use of a common language ?

2. Assuming that there is an advantage, is it possible to attain the end in view, and if so, how ?

I.

That the adoption of a universal language would prove a great boon to travellers and tourists need hardly be mentioned. Anyone who has had occasion to travel abroad, and to deal with others than hotel porters, guides, or that small minority which constitutes the cosmopolitan element to be found anywhere, will immediately agree. But it is not proposed to touch this point to-night. The Author limits himself to the use to which such a language might be put, for scientific and technical purposes.

The question presents itself under four principal aspects which will be reviewed in turn.

First.—In considering the study of science in its various branches, one cannot help being struck by the fact that the science of the day has become, to a considerable degree, *specialised* and *international*. The days are no more when a man, like Pic de la Mirandole, could be said to know everything of every science. Now-a-days, the amount of knowledge available upon a given subject has become so considerable, that after having acquired a general education, one must specialise in a particular branch. And this very specialisation has resulted in this : that no man can be satisfied with only that part of the knowledge on a particular subject which can be acquired in his own land, and no man can rely only upon the research work carried out by his fellow-countrymen to keep him fully abreast of the whole progress of science in his own special sphere of activity.

In the sphere of civil engineering, although the British engineer has achieved remarkable things which have won him the admiration of his foreign brethren, it cannot be denied that, in his turn, he has learnt a good deal of late years from their experience. For instance, it is a common occurrence for British Harbour Engineers (and also for deputations of their Boards or Committees) to go and inspect thoroughly the arrangements and the management of harbours in Holland, Germany, France and elsewhere ; and to have to refer to text-books and technical reviews or reports on the subject, written in French, German, and even Russian or Italian, and there is hardly any branch of engineering to which the above does not equally apply.

In the sphere of medicine, and biological science, all nations have been obliged to study closely Russian research work. In wireless telegraphy, the light came originally from Italy and France.

If the Author may be allowed to bring in his personal experience, he may say that, for the study of a special subject like reinforced concrete, he has had (and most of those who are interested in the subject have been similarly placed) to peruse German, French, Russian, Spanish, Italian and Dutch text books, reports on experiments, etc., either in the original language or a translation, in addition to English literature of the same class.

Second.—If abandoning pure book study, we turn now to the more practical side of the carrying out of engineering undertakings or the pursuit of research work in places abroad, we find that the activities of many among us take them to places where it becomes very necessary to have intercourse with people unable to speak, or understand, or even write properly, any of what we may call the leading languages of the world ; English, French and German. It becomes necessary to deal with Spanish, Portuguese, Greek and other languages. Should a man be

expected to devote thousands and thousands of hours to the study of all these languages ? To master a foreign language means very hard work. If we must acquire, two, three, or even four, as we feel now almost compelled to do, it means a considerable waste of time, which could be more profitably occupied in other ways (as far as the community is concerned), if all engineers and scientists were able to understand an international language.

Third.— But this is not all. An important feature of scientific work, in modern times, consists in the holding of frequent international congresses. To give an idea of the growth of this practice, one may mention the fact that, during the period of ten years extending from 1851 to 1860, one can find record of only 19 international congresses of all kinds, whereas, between 1901 and 1910, the impressive total of 884 was reached. That these congresses as at present conducted prove very useful, is undeniable. That they would be considerably more useful if all their members could *really* and *thoroughly* understand each other, by using a common language, will be conceded at once by anyone who has had an opportunity of attending one of them.

As a rule, at these congresses, four languages are officially recognised for the writing of the papers and for their discussion—English, French, German, and either Italian, Spanish or Russian, as the case may be. Generally, all the papers are translated into the three other languages. This represents a considerable amount of labour, and a very great cost ; a cost, indeed, which tends to render the entrance fee considerably higher than would be the case if all this translating and printing work had not to be done and paid for out of the fees. But, while this constitutes a real waste of time and money (although it may benefit a few translators and printers) it is not the worst aspect of the question : the crisis comes, when all the delegates assemble together for a meeting and the discussion of the papers.

If, by hard work, one manages to get a knowledge of foreign languages sufficient to allow of reading and writing, it is quite another matter when one comes to speaking. Years spent by a Frenchman in England do not allow him, alas, to acquire the correct pronunciation and accent of the English language, which he may admire but finds terribly puzzling. On the other hand, the Author has still to meet the Englishman, or the German, whose French is not, undeniably, and immediately stamped " British made " or " German made " as the case may be. Somehow, however, an Englishman and a Frenchman manage to understand each other when speaking either of their respective mother tongues. But, how very much more difficult for a Frenchman to understand the English of a Japanese, or of a Spaniard !

At a recent congress, the attempts of an Italian scientist, who had evidently never lived in France, to take part in the discussion, in French, of one of the papers, so thoroughly baffled the British, German, Russian and other members of the Congress, that they were not long in getting away, quietly, and the earnest remarks of the Italian representative were completed before empty seats !

This is how a Russian delegate to a recent medical congress sets forth his impressions :—" Many have returned with a bad impression . . . . No communication is understood by all present, whatever be the language used. The result is that German reports are studied and discussed chiefly by Germans, French ones by Frenchmen, and so on. Now, since national medical congresses take place yearly at home, of what use is it to a German doctor to come to an International congress to hear other German doctors ? " It seems unnecessary to labour the point any more ; all will agree that the usefulness of international congresses would be increased tenfold if all the proceedings could be held in a truly international and common language.

Fourth.—We come now to a point which has an important bearing on the development of international science, viz. : the present high price of technical books.

In many fields of research, years of study are spent by scientists in the compiling of documents and the writing of treatises, which constitute sometimes, indeed, the work of a lifetime. Nevertheless, the number of men who are likely to purchase any of such works in the author's own land is so limited that the mere material cost of the issue renders the price of the publication very high ; often so high as to prevent many workers from possessing themselves of a masterly book that they would like to have, but which they cannot afford to buy. Yet, authors get practically nothing from the publishers, to recoup them for their labours ; frequently, indeed, they have to pay to get their works published at all, especially those treating of highly specialised subjects.

If such is the case for scientific or technical treatises published in the authors' own country, it is obvious that the difficulty increases considerably when it is attempted to publish, abroad, translations of the work at paying prices. Not only, therefore, is there lack of adequate reward to the authors, but the scientific public of foreign lands may not have a chance, for a long time at any rate, of reading works of great interest in full ; they have to be content with any analysis or extracts which may possibly be published in technical journals.

If, on the contrary, technical books were published in a truly international language, the number of their possible readers would be increased to a large extent, and in consequence they

might be published at perhaps a quarter, or even less than a quarter, of the present cost. This would increase their sphere of influence considerably, thus benefiting the community at large, and at the same time rewarding the authors more adequately.

And the fact that the authors themselves would write the book in the common language, would obviate the errors of translation which are so frequent, even when great care is exercised. A good translator may, without realising it, fail to grasp thoroughly the writer's meaning. Moreover, he may not be altogether to blame, for even technical dictionaries are not always absolutely accurate ; and indeed one could give many instances of words which are used in various lands under exactly the same form but which do not possess exactly the same shade of meaning in every one of them ; thus causing many misunderstandings in translation.

The Author hopes to demonstrate in a few minutes, that the above is no idle talk, or a mere utopian or cranky idea which cannot be realised in practice. For the present he feels sure that every one will agree that, if it were possible to have an international scientific language, which all of us could use as easily as our own mother tongue, it would indeed be worth having !

II.

Is an international scientific language possible ? The past enables us to reply in the affirmative, and at the same time gives us indications as to the conditions that such a language must fulfil.

1. We know that, a few centuries ago, Latin was, in fact, the medium through which the great philosophers corresponded, and wrote their most valuable works. There is, therefore, nothing preposterous or novel in the idea of an international scientific language.

Even now, Latin is used to a certain extent in classification work. Botanists, in this country, often find occasion to refer to the classic work "Genera Plantorum," by Bentham and Hooker. It need hardly be mentioned that scientists of all nationalities recognise a daisy under the name of *Belles perennis* and a donkey under that of *Equus asinus ;* they possess, therefore a kind of universal language, so far as names are concerned. However, for general purposes, Latin has been entirely abandoned and the reasons for this are simple enough : first, Latin is an exceedingly difficult language. Although most of us have studied it during some 6 or 8 years of our school life, how many among this audience would be able to translate properly into Latin the first two or three paragraphs of any morning paper, not to

speak of a technical work ? This leads us to the second shortcoming of Latin, viz., that it is a dead language, totally unsuited to the expression of ideas, or to the statement of facts, which could not have been dreamed of in the days of Rome.

It may be a surprise to many to hear that there are still two or three newspapers published in Latin and dealing with modern topics ; needless to say they are meant solely for the amusement of the learned. But the portentous periphrases to which they are driven in describing tramway or motor car accidents, the rank obscurity of the terms in which advertisements of the most ordinary goods are veiled, are sufficient to shew the utter impossibility of using Latin as a practical language of modern science. Without more ado, and for the same reasons, we may put Greek in the same basket.

2. It may then be asked : Would a modern national language prove acceptable and suitable ? We know that French has been, for years, recognised as the official and international language for diplomats, and if, for a minute, we chose to ignore the claims of other languages such as English or German to be adopted in its stead, it is again a proof that, for men of a certain calling and of many different nationalities, an international language is a practical possibility. However, what do we find now ? That, although in principle French is still the official language of diplomacy, a number of nations have a tendency to use their own language in their written communications. For instance English diplomats write in English and German diplomats in German, although replies sent by foreign Governments are in French. In South America, Spanish is largely used.

At once, we thus come across one of the most essential conditions of success for a truly international language : that, owing to universal race pride and prejudice, it must not be one of the national languages, but on the contrary, a *neutral idiom.* And the immediate reply to those who say " Why should not English be the language of the world, seeing that it is already spoken in so many lands ? " is that Germans think the same of German ; Frenchmen of French, and other nations of their own languages.

It is true that the number of English speaking people is computed at about 120 millions ; but Russia follows closely with nearly 100 millions, Germany with nearly 80 millions, and the progress as far as numbers are concerned, of the two last named during the last two decades, is perhaps more rapid than that of English. So that the fight for language supremacy between England, Germany and Russia, would be a stiff one, not to speak of the resistance offered by the older nations, like France, Italy, Spain, etc., and the younger ones like the Balkan States, to the universal and official adoption of a foreign language. It

is obvious that the moral and material advantages which one nation would derive from the adoption of its own language as "world language" would be so great that all the other nations would soon combine to prevent such an occurrence. Besides, as stated above, all national languages are very difficult for foreigners owing to their irregularities.

Naturally, it must be borne in mind that when using the words "universal language" it is not suggested for a moment that there is the slightest chance of any one language ever becoming the usual language of all men. Reference is made only to an *auxiliary* language for intercommunication. It is quite evident that national languages will continue to exist in every land. Even small communities annexed by powerful neighbours have shewn, of late, proofs of wonderful and renewed vitality toward the maintenance of their mother tongue, *e.g.* Bohemian, Hungarian, Polish, Irish and Welsh.

So far we have seen :

(*a*) That an auxiliary and universal scientific language would be a great boon to the world, and,

(*b*) That certain languages have, in the past, been fulfilling the said desiderata for a time, but have ultimately been abandoned (as universal languages) because they were either dead languages, like Latin or Greek, unable to accommodate themselves to changing conditions, or else because, being living languages, they gave rise, like French in diplomacy, to jealousies on the part of the other nations. Therefore, the ideal international and auxiliary language would seem to be an *artificial and neutral* language, which should be as *easy as possible to acquire* and also *as international as possible*, in aspect and formation, so as to appeal to most nations almost equally.

3. The next question is :—

Does such a language exist at present ? Most emphatically, yes ! And its name is *Esperanto*. Many attempts have been made to solve the problem. Esperanto embodies the best points of all previous attempts and is almost perfect, for all practical purposes. During the last 20 years it has progressed very rapidly and gained official recognition by many Governments and Public Bodies. It is not proposed to describe the language in this paper. Those interested may apply to the British Esperanto Association, 133, High Holborn, London, W.C.

But some proof must be given that it fulfils the requirements above stated.

(*a*) *It is a living language.* Built on a foundation of *root-words*, its vocabulary grows up according to need, by means of a clever utilisation of the principle of affixes. Such a growth is characteristic of a living language. What is more, it is a very live language. Made public in 1887, Esperanto did not progress very

fast at first. In 1901 one counted only 26 societies devoted to its spread, but at the end of 1911, this number had jumped to more than 2,000. The number of books published in Esperanto was 1837 at the end of 1912, and there are about 100 monthly or weekly periodicals.

(*b*) *It is international and neutral* because its root-words were selected from among the leading living languages, and because the root which has the same meaning in the greater number of these languages was selected, as a rule. In other words, the founder of Esperanto, Dr. Zamenhof, was largely guided by the principle of maximum of internationality for his roots. Hence it follows that any European who reads, or hears, Esperanto for the first time, finds that he knows already about 70 to 75 per cent. of the words. Whatever his nationality he feels immediately at home with Esperanto.

(*c*) *It is most easily learnt* because all the difficulties of grammar, syntax and pronunciation, all the irregularities which are to be found in national languages, have been carefully removed, and because there are no *exceptions.* The result is that a man of education similar to ours can easily master the Esperanto Grammar in an hour ; another quarter of an hour would unveil the mystery of word building ; and, as this is no exaggeration, the Author would undertake to enable any member of this Society, after two hours of study, to translate with ease (if perhaps a bit slowly at first) *any* Esperanto text and to understand a good deal of a slow conversation. Practice soon brings fluency, and the Author gives as a fact that, within two months of his having taken up Esperanto as a hobby, and studied it only during railway journeys, he was able to write in Esperanto a very acceptable article of ten pages which was published in *The International Scientific Review.* The subject matter was " Reinforced Concrete " and it may be added that this subject had never been dealt with previously in Esperanto. Consequently, it became necessary to coin new words, which however were intelligible to every Esperantist. This personal experience is given as an illustration of the possibilities of the language. On the other hand, the Author feels absolutely certain that he would never have been able to write a similar article in either English or German within at least 2 years from a start with the study of these languages.

One of the great points regarding the ease of Esperanto is that it is so accurate and precise. The great principle of " one word, one meaning " works wonders. There are no synonyms, no homonyms.

(*d*) The language *must lend itself to the technical requirements of every science.* The Author has now before him the catalogue of a German library which possesses an extensive Esperanto

department. The following are a few titles, picked out at random from this catalogue, of books already published in Esperanto: "Analytical Geometry," "Notes on a new Cure by Artificial Sun Baths," "Elements of Optical Photography," "Elements of Pure Geometry," "Foliatary Geometry," "Diseases of the Heart," "Five Lectures on Bacteria," "Human Radiations," "The Construction of Sun Dials," "The Thermotherapy of Aix-les-Bains," "Visions of the Infinite," "Notes on the First Road Congress," etc.

It seems therefore that Esperanto has already been utilised in many branches of science and utilised with every possible ease.

(*e*) It has still to be proved that if Esperanto, as we have just seen, is of easy application as a written language, and likely to prove of great use for the preparation of papers and reports for international congress, it will *prove equally suitable when it comes to their public discussion.* The question is: "Have Esperantists ever met in Congress, and if so what has been the result?" In fact this is the crucial test of an auxiliary universal language. Are Esperantists able to understand each other? Are not the national characteristics of their mother tongues likely to render the pronunciation of a Japanese esperantist unintelligible to the Swede, to the Hungarian, to the Chilian, the American, etc.?

It was felt by those who had studied the question that matters would be helped considerably by the systematic exclusion from Esperanto of all the difficulties of pronunciation met with in the national tongues. Esperanto does not know the English *th*, the French *u*, the Spanish *j*, the terrible nasals, *on*, *an*, *em*, which prove such a stumbling block to Britishers when they learn French or Portuguese. Still, before the first Esperanto International Congress, held at Boulogne in 1905, many Esperantists were a bit anxious. But the result was all that could be wished for, and the same success was repeated in subsequent years at Geneva, Cambridge, Dresden, Barcelona, Washington, Antwerp, Cracow and Bern: a truly international list.

At these Congresses, the attendance varied from 700 up to 2,000, and 40 nationalities were represented, at times. It is worthy of notice that, in addition to the general meetings, sectional meetings of delegates interested in special branches are a feature of these Congresses. For instance, the Author attended sectional meetings of the *International Scientific Association* which were under the chairmanship of the veteran scientist General Sebert, of the French Institute, Member of the Académie des Sciences, and at which were discussed the most varied questions, such as: Note on magneto-optical phenomena; Report of the International Commission of Electro-technics;

Essay on an international standard of money; Unification of time. The proceedings were quite interesting and easy to follow. Out of curiosity the Author went to meetings of other specialists at the same congresses, including those of the International Society of Pharmacists, International Association of Teachers, and the International Union of Catholics. Everywhere the discussions were quite easy to follow. There are many other similar societies holding sectional meetings of their own, such as: The Universal Association of Esperantist Doctors, The Esperantist Psychical Research Association, The International Association of Esperantist Lawyers, even the International Association of Police Officers! Esperanto is therefore quite suited to the requirements of such International Congresses. In fact, and this shews the recognition it begins to receive, at the *First Pan-American Scientific Congress,* held at Santiago de Chili in 1909, the following resolution was passed:—"Considering that the Esperanto language is in practical use by thousands of persons in all civilised nations, the First Pan-American Scientific Congress recommends it as a neutral international language which deserves an important place in the programme of instruction of the American nations."

(*f*) In order to bring the argument to an end, it should be shewn also that *Esperanto has proved to be the means of lowering the cost of international books,* by rendering them accessible to a large number of readers scattered all over the world. Unfortunately statistics are not yet available, Esperanto being still comparatively young. Attention must therefore be confined to one fact which may be taken as an indication of the potential capabilities of the language in this respect.

Last year, the New Testament was published in Esperanto by the British and Foreign Bible Society. From information obtained, it appears that the sales during the first 12 months following the date of publication exceeded 8,000 copies. As a comparison one may mention that the sale of translations of the New Testament, by the same Society, in the same year, amounted to about 5,000 copies in Italy, 2,000 in Portugal and 3,000 in Belgium.

The Author is quite aware that he is far from having exhausted this very wide subject. His only desire was to draw the attention of the members of the Society to a problem which he considers as of great importance. He can only hope to have succeeded in arousing a certain amount of interest on the part of his colleagues, and that some of them may feel disposed to inquire further into the matter.

Discussion.

The **President** proposed a vote of thanks to Mr. Gueritte for his very interesting paper. Mr. Gueritte was to be congratu-

ated, not only for having written an admirable paper dealing with a subject that was new as far as engineers were concerned, but also on having attracted ladies to the meeting. He was sure that all the members of the Society had great pleasure in welcoming ladies to their meetings, but the occasions on which they had succeeded in persuading them to attend were exceedingly rare. He remembered only one such occasion, and that was many years ago. The Society of Engineers regarded itself as a progressive society, and in asking Mr. Guerritte to read this paper they believed they were advancing something which would be of material advantage to the profession. The paper was very clear and put before the Society a matter of very great importance, viz., a means of easy communication useful to engineers of all nationalities. It was, however, an exceedingly difficult thing to get people to take up any new idea, and especially when the new idea being brought before a Society of engineers was not in itself an engineering subject. Personally he had always looked upon Esperanto as being as difficult to learn as French or German, until he heard Mr. Harrison Hill state in song something to the effect that one might obtain instruction in Esperanto for a penny, and might moreover learn it in a week. That song had set him thinking, and the more he thought the more he was led to the conclusion that Esperanto would be useful to him personally. He felt sure that other engineers would see that in Esperanto they had something of exceptional value.

The vote of thanks was carried with acclamation.

Mr. Etchells said that in Esperanto they had something which would be a help to technical progress thoughout the world. He had sometimes doubted the possibility of speaking a foreign language with the perfect accent of a native. He had met with foreigners who had been in this country for twenty years, and even then he could detect that they were not of English birth. He was in Geneva some years ago at a dance where Esperanto was used, and he endeavoured to ascertain whether he could discover the nationality of the various members of the company. He decided that a certain group of girls were English. He thought that they came from Gloucestershire, but on talking to them he discovered that they came from the Swiss mountains, and they had only learnt Esperanto for a month. Another of his experiences was that when foreigners called upon him accompanied by an interpreter, he had on several occasions noticed the international emblem, and from that moment the services of the interpreter were unnecessary. Russians, Poles and Hungarians and Czechs had called upon him, under these circumstances. He could affirm, after an experience of ten years, that an inter-

national language was quite practicable. He believe d, however that even the best international language was capable of improvement, but upon that subject he would not say anything now. He strongly supported the idea of an international language, and he believed that Esperanto was far superior to any previous attempts at the solution of a problem which had interested that great mathematician and scholar Liebnitz. As to the adoption of an international algebraical notation for engineering formulæ, he believed that it must be the outcome of an international language.

Sir William Collins said that he had listened with very great interest to the paper, and he congratulated Mr. Gueritte upon the admirable and succinct manner in which he had dealt with the subject. He recalled with pleasure that after the Cambridge Congress of 1907 he had met Dr. Zamenhof, the founder of Esperanto, on the Terrace of the House of Commons (of which he—Sir William—was then a member). From his own personal experience of many International Congresses, Sir William fully confirmed what had been said about the waste of time and money in the translation and retranslation of the proceedings into three or four official languages, none of which was understood by all the members, and of the difficulties which constantly met many members of such Congresses, who, while perhaps able to read one or more of the official languages, were unable to speak them or to understand them when spoken. An international language such as Esperanto was advantageous on account of the international jealousy which would exist against the use of the language of one particular nation. Such jealousy could be avoided by the use of Esperanto, which took the common measure of several languages. One's own nationality was liable to be discovered in the attempt to address an audience in a foreign tongue, which he understood was not the case with Esperanto. Those superior people—said Sir William—who think that an artificial language is a sin against philology, might be referred to academic authorities like Professor Boirac, of Dijon University (a well-known leader of the Esperanto movement). Speaking as one who is deeply interested in the cause of peace and goodwill among the nations, Sir William said that that which ensured special sympathy for Esperanto was the fact that it was a means whereby the peoples of the world could communicate one with another, thereby helping towards good understanding and consequently the international friendship of mankind. He congratulated the author upon his paper, and the Society upon their enterprise in inviting the reading of such a paper.

Mr. Harrison Hill said that he remembered staying at a boarding-house at which there was a lady who was a teacher of

languages, and he taught her Esperanto in a week. Two or three days after his return to London he had a letter from her written in excellent Esperanto. Sir William Collins had alluded to Esperanto as a great aid to peace and a good understanding among nations, and it was from that point of view that he would speak of it on this occasion. He was not qualified to speak of it from the point of view of an engineer. He was speaking from the point of view of an ordinary citizen of the world who loved his own country and loved to see other countries. In that capacity he had experience of Esperanto. Mr. Etchells told the meeting just now that it was impossible to discover the nationality of a person from his manner of speaking Esperanto, and he (the speaker) could quite confirm that statement. He had had an audience of twenty-three nationalities listening to him, and they all understood him perfectly. As one of the Vice-Presidents of the Esperanto Society he wanted to thank the Society of Engineers for inviting him to this meeting, and Mr. Gueritte for preparing such a valuable paper.

Mr. F. M. Sexton said that his son had translated a technical paper into Esperanto, and it was published in a scientific journal It could not be said that the translation was so easy that the ability to make it could be acquired in a week, but it would be quite easy. to do it in a way which would be perfectly intelligible to any foreigner, and that was a thing which could not be done under any circumstances whatever with a national language. It was quite possible that many persons failed to realise what the translation of a technical paper required. A person understanding French or German fairly well would find difficulties when he came to translate a technical paper into either of those languages : but with Esperanto it was quite possible to start from the fundamental idea of a word and translate in such a way as would be quite intelligible to a foreigner. The Esperanto Journal to which he had referred treated practically of the whole range of science, and it would prove the amazing fitness of Esperanto for an international work. He would venture to say that any engineer would be able to read 90 per cent. of the scientific papers published in Esperanto without any previous study of that language. They might be read practically at sight. He was sure that all the members of scientific associations were aware of the necessity of making abstracts of papers for scientific journals. Esperanto would be fitted for the making of such abstracts, and the same abstract would serve for various countries. Authors could make abstracts of their papers, and a paper could be sent forth in precisely the same terms in all countries. This would be a better method than each country having to prepare a different abstract. He believed that

Esperanto had a very great future before it in the scientific world, and he thought that that was the only aspect of the question with which they ought to deal to-night ; and if the Society would use its influence to push forward the employment of Esperanto as a means of communication in scientific subjects it would be doing an exceedingly useful work.

Mr. B. Chatterton said that he first met the author some years ago at the Cambridge Congress, which was attended by visitors from different countries. He soon found out the value of Esperanto, and it would be worth while for engineers to devote all the time they had at their command to gain mastery over it. When they came to the establishment of an international language they struck unthought of difficulties, and he thought the Esperantists themselves were the first to acknowledge it ; but there was no doubt that the progress of international feeling and the desire for communication between different nations would be favourable to the establishment of Esperanto. He thought that the paper which the author had given them that night had been most succinctly arranged, and had given those who were not esperantists a very nice account of the reasons why they should take up Esperanto. At the Cambridge Congress which took place in 1907 he met a Russian, and only last week he received a letter from him written in Esperanto, though he had never heard from him in the interval. The writer asked him to be kind enough to obtain for him some information about engineering subjects. The author of the paper had alluded to the difficulties which arose in carrying out works. During some work which he had to carry out in Hungary he went to a part where the English language was absolutely unknown. He was away in the mountains for five weeks, and he would have been absolutely nonplussed if the chief clerk of the firm, an Italian, had not been able to speak French. For five weeks he had to talk French to this Italian clerk. In travelling on the Continent they found English spoken in the principal places, but the moment they went off the track to the mountains or any other part English was practically unknown, and this question of language came up at every point. The more one travelled and studied, the more one realised a sympathy towards the history, the language, and the scientific attainments of foreign countries, and the more they had evidence that the Esperanto language was one of the needful additions to humanity to enable men to live in a higher and better plane than before. Esperanto would have no field of usefulness unless there was beneath it the idea of international relationship. To a person who concerned himself entirely about his own country and his own doings, Esperanto was useless ; but to a person who had wide sympathies and a

desire to enter more fully into the knowledge of things of other countries Esperanto was of the greatest value. Esperanto was, in his opinion, the warp and woof of all human speech, and engineers would naturally desire to be able to transfer their ideas accurately from one brain to another, and for that reason they would desire to have a most perfect vehicle. Esperanto was a language with sixteen rules with no exceptions, and it helped to develop and cultivate a person's philological faculties. For that very reason he thought that in years to come every instructed person in the world would speak it. The vehicle which we had to express our thoughts was one of the most potent means of developing and clarifying the brain.

Mr. A. Honeysett said that he was the first person in this country to suggest the use of Esperanto to engineers. This was soon after the Cambridge Congress of 1907. The letter he wrote on the subject produced a good many replies from engineers, and it was found that there was a certain amount of interest taken in the matter. He shortly afterwards set about compiling an engineering vocabulary for his own use, but it seemed like a labour of a lifetime to compose a technical dictionary in a new language. In Esperanto all the technical words had to be invented. By taking the necessary roots to build up words he met everything that could be required in every branch of engineering. The number of words that he had to make was about 1,200. He did not think that there was anyone there who could not have done the same. The possibility of speaking in Esperanto and being understood was a point which aroused a good deal of doubt in the minds of many persons ; but as a matter of fact, Esperanto was very easy to understand. Every sound which could not be understood was eliminated from the language. A great point in the value of Esperanto was the ease with which it could be pronounced.

Mr. C. R. Enock said that he should like to ask whether there was not any other language that they could adopt. He happened to know Spanish. Spanish was very simple, and he believed it the easiest language on earth. It was spoken in the whole of South America and in many other parts of the world. He thought that it could be adopted as a universal language. He admitted that engineers needed to speak a common language but why should they not take up an existing language for that purpose ?

Miss Laurence suggested that an experiment might be made as to the relative ease of learning Spanish and learning Esperanto by taking two persons who knew nothing of either and setting one

to study Spanish and the other to study Esperanto for two months and then comparing the results.

Mr. W. C. Easdale said that every person thought that the language of his own country was the best, and therefore it would never be possible to get all nations to adopt any existing language for international use. This objection would not apply to Esperanto.

Mr. Archibald Sharp said he thought that the Society of Engineers was to be congratulated on having this paper read. He had been trying for the last twelve months to induce another engineering society with which he was connected to accept such a paper for discussion before its members. Engineers were dealing with materials and with processes, and they were endeavouring to standardise them. Why should they not attempt to standardise language, especially in the matter of technical work? He thought that Esperanto was bound in the near future to supply a want that they all felt, namely, the necessity of getting to know what was being done by their professional brethren in France and Germany. By some means they got to know, but still it was a slow process. As soon as Esperanto became more widely spread among engineers that work would be facilitated.

Mr. Etchells, referring to the speaker who advocated Spanish as an international language, said that Spanish was a very good language for those who knew it, but the accent in that mellifluous language was very variable. It might happen that, in time, when there was one dominant race on the earth—either an Anglo-Saxon Federation of nations, or possibly a Pan-German Federation, or a Russian or a Chinese Federation—there might be one dominant language spoken as a means of international communication among the peoples of the earth, but that might be a thousand years hence, and mankind wanted something simpler to be going on with; and among the languages that were possible now Esperanto formed the best basis. Privately he hoped that it would be improved.

Professor R. H. Smith said that the meeting had been too much confined to Esperanto. He had devoted some little time to the study of that language, and had become able to read it without very great difficulty. He thought that the ease with which it might be acquired had been exaggerated that night, although he admitted that it could be learnt more quickly than any of the other four or five languages with which he was acquainted. He was glad that the subject had been brought before the Society because he did not think that it had been

sufficiently considered by the English nation, and, as far as he had discovered, very little attention had been paid to it by English engineers. He was wholly favourable to the idea of an auxiliary international language, but he could not have the smallest sympathy with the idea that Esperanto was to be put forward as a substitute for the different languages of the different races of the world. Esperanto or some similar language would serve for all common purposes, such as giving orders or calling a cab, and finding out the time of a train ; but to find out the character of the people or country one must speak to them in their own language. Still he recognised the great facilities which might be obtained by the use of a universal language. He was sorry that the English races had not paid more attention to Esperanto than they had, more especially because they were so numerous. The paper mentioned 150 millions, but he thought from what he had heard that they numbered 250 millions. He was sorry that he had never heard Esperantists admit until that night that there were any defects in the language. This was the first meeting at which he had heard a suggestion as to the possibility of any improvement in Esperanto, although he had heard from experts that it needed great improvement.

Mrs. Margaret L. Blaise said that Mr. Enock had alluded to the fact that in his opinion Spanish would be a much better language to set before them as an international language. Englishmen, he said, were so very conservative, and he had noticed that Englishmen did not largely participate in the Esperanto movement. To him she would merely say that if Englishmen were so conservative as to object to learning another language, how much more they would object to Spanish, an entirely foreign speech, than to Esperanto which contains so many elements of their own tongue. Again, if Englishmen were somewhat—not so very much, however—behind in this progressive movement, it was because Esperanto was first introduced in Russia, and then into France and Germany, and had spread through these lands into England, which country had only in comparatively recent years become aware of its immense importance. Professor Smith believed that even if Esperanto became useful for commerce it would never be used intimately, never suffice to teach the members of one nation the real home life and the intimate thoughts of the members of another. To that she would reply that Esperanto was applicable for this purpose than any other language could be, and in support of her assertion she would ask them to believe that she had many intimate friends in other countries whom she knew closely and with whom she could converse or correspond only in Esperanto. One further point had been raised. What about

Ido—a language said to be more perfect than Esperanto and to do away with its reputed difficulties ? She thought that that objection was now such an old story that there was little need to go into it. The Idists could prove nothing so convincing as Esperantists could. It seemed to her that they had no facts to bring forward, though they always attempted to assail their assertions. Some doubt had been expressed as to the time taken generally for learning the language, as to which she could assure them that although the time often varied and Esperanto could be learned in a week or two, it was better to say that it was usually learned in six months. For evidence of this she would mention the fact that in the North of England she had instructed some five hundred pupils, mostly in the Technical Schools, and these pupils needed generally some six months, with one lesson per week and an hour or two or three for study, in order to converse and correspond in Esperanto with a fair amount of fluency.

Mr. H. Bolingbroke Mudie said that it had been suggested that Spanish should be set up as an international language, but the Spanish verbs were too much for most people. He had spent a great number of hours over the Spanish grammar. He was quite sure that ninety-nine out of a hundred Englishmen who had made an effort to learn Spanish and were at home in reading a Spanish book would be unprepared to get up and speak on any subject in Spanish to a Spanish audience. If an existing language were chosen for international use, international jealousies would have to be overcome, and he was afraid that such jealousies would always remain. When a thing was new it generally met with opposition. When the steam engine and the telephone were new, who was enthusiastic about them ? He was glad that just at the present time when the educational world was waking up they were able to bring Esperanto forward as an important matter and have a discussion upon it. They had been told that one week was not a sufficient time in which to learn Esperanto. He had known case after case in which even school boys had acquired a knowledge of Esperanto in an incredibly short space of time. When he started to learn Esperanto twelve years ago it did not occur to him for a single moment that he should derive any practical benefit from it, but in travelling he had derived an enormous amount of benefit from it. Professor Smith had touched upon the defects of Esperanto. The language was started twenty-six years ago and there was only one person in the world who knew it, but now it was known by thousands. How was it that it seemed to have pleased everybody more or less ? If anything better than Esperanto were brought forward Esperantists would receive it with open arms. They were at bottom people with common sense, and if anything better were shown to them they

would overcome their original prejudice and accept the better thing. Certain little things which appeared to be difficulties in Esperanto had been overcome. Whatever time was required to learn Esperanto a person would have to take ten times as long in learning an existing language. What could be more useful for international purposes that simplified European languages ? He would suggest that, in future international congresses, notice should be given that Esperanto would be one of the languages which might be used in the debates. In conclusion, he wished to thank the Society of Engineers for having put this most important subject upon its agenda. The international world always looked at England as the leader in progress and he hoped that the holding of this discussion would have far reaching results.

The following written communications were received :—

Mr. W. Noble Twelvetrees wrote :—I have listened with considerable interest to the able paper by Mr. Gueritte, who very wisely abstains from any description of the artificial language known as "Esperanto," and confines attention to the main question of a standard international language for engineers.

The desirability for standardisation in engineering practice has been amply demonstrated by the invaluable work of the Engineering Standards Committee, and the feeling of engineers in favour of a standard algebraical language was clearly manifested by the influential discussion, on the subject of "Standard Notation for Engineering Formulæ," which took place at a meeting of the Civil and Mechanical Engineers' Society shortly before the formation of the Society of Engineers (Incorporated).

The author puts forward so clearly the advantages to be secured by the adoption of an auxiliary language to serve as the medium of intercommunication between the engineers of different nationalities that little remains to be said on this score. The claims for Esperanto for acceptance are fairly stated in the paper, and have been somewhat enthusiastically urged by several gentlemen who have taken part in the discussion. It may, perhaps be granted that Esperanto is capable of some improvement on points of detail, but in that respect it forms no exception to all other things mundane.

So far as my limited experience extends, I have reason for believing that Esperanto would adequately fulfil the purpose discussed by the author. Probably a good many engineers, including members of this Society and members of kindred organisations, may share the same belief, but it is morally certain that the progress of the new language among engineers will be extremely gradual, until the leading professional bodies in this country and abroad take concerted action of such nature as to render familiarity with Esperanto desirable or necessary. For

example, if the Society of Engineers, with the co-operation of the leading institutions or alone, could persuade the French Society of Civil Engineers, the German Society of Engineers and one or two other representative organisations abroad to join in a movement for the publication of Esperanto editions of, or Esperanto supplements to, their respective Proceedings or Journals, a very large number of British and Continental engineers would at once realise the necessity of commencing a study of the language. Similar benefit would be derived from the issue of an international engineering newspaper under the auspices of the leading societies and institutions.

Unless something of the kind can be done I certainly do not think that any material advance will be made for a long time towards the realisation of the ideal put forward by Mr. Gueritte for the standardisation of engineering technical literature.

Mr. Richard Twelvetrees wrote saying that he had no doubt that a universal language would be of immense practical value to engineers, and as far as he could judge, Esperanto appeared to possess all the features to make it suitable for general adoption.

With regard to the language difficulties met with in various branches of the profession perhaps automobile engineers experience some of the most striking examples. In the early days of the motor industry new ideas came primarily from the Continent, and even in the present day those who are interested in the development of the automobile cannot well afford to shut their eyes to Continental practice.

The mere translation of technical publications from French, German and Italian into English occupies a considerable amount of time that would be spent more advantageously if, say, one periodical from each country were published in Esperanto.

A motor vehicle is built up from components, not infrequently reaching the number of 3,000 in a single chassis, and the idea of learning the names of these parts in at least three different languages is rather appalling. It is quite possible, too, that the involved phrases describing various parts, such as "piston-gudgeon-pin-set-screw-lock-nut," and even more lengthy examples, which are common in the German language, would be greatly simplified in a technical dictionary of Esperanto.

Again, international conferences and exhibitions now organised from time to time would be far more valuable than they can possibly be at present if engineers would unite in adopting a language on the lines of the one described by Mr. Gueritte.

Mr. F. H. Wardley wrote :—It is a pleasure to have such a paper from a highly qualified technical professional man and able

linguist. We have been waiting for years for someone combining these qualities to give a lead in the interests of engineers, and to help in the formation of an international paper devoted to engineering. One sees the success attending the specialist groups of Esperantists, and cannot understand why medical men, for instance, should be more enterprising in this respect than we have been. Certainly so far as I am aware no other attempt to establish an international helping language has had anything like the same measure of success in overcoming jealousy, difficulties in word formation and pronunciation, inflexibility in application to technics and the varied word order of sentences in national languages. The author's article in *The International Science Review* was read by me some three weeks after first acquiring an Esperanto key. At that time little was known of reinforced concrete in this country and it was with a feeling of delight that one read those specially coined words he mentions. They were so precisely self-explanatory to anyone knowing the elements of the subject. From experience since that time of articles in Esperanto on subjects hitherto unknown to me, I do not doubt that anyone reading the author's explanation would have no difficulty in understanding the subject even if such rudimentary knowledge were lacking in the reader.

To the engineer, especially if he be with a private or a manufacturing firm, one may say that a knowledge of at least four languages is necessary if he is to keep up to date with the progress of his special study, for although certain abstracts of foreign papers may be available yet though faulty translation or the cost of publishing in a series of languages the subjects are neither treated as fully nor as accurately as they would be if only one translation were necessary. Again, an edition in any given language may be insufficient owing to the different terms used in the territory covered by such language, e.g., the English of America differs from that of the British Empire in railway nomenclature ; the American switch is not entirely equivalent to the British word, but a frog is the same as a crossing. So the Spanish of Spain differs in pronunciation and often in exactly parallel meaning from that of Southern America. As the author points out it is far easier to translate into Esperanto than into any other foreign language, and with very little study a writer himself can communicate with a multitude of foreigners with perfect assurance that his exact meaning will be conveyed. How often do we find translations made of technical matter with the most ludicrous results. One has only to think of certain pamphlets issued in English relating to foreign excellent inventions and products to recall the joyous, and, in some cases, utterly bewildering moments to which they gave birth.

The time necessary for picking up a working knowledge of

Esperanto is small, so small that manual workers readily acquire the facility of expressing themselves in this medium. For instance, I know of a railway signalman who corresponds with Russian, French, German, Italian and Japanese confreres, and even with the august heads of traffic and other railway departments abroad.

As a means of exchanging experiences and discoveries at international congresses some universally understood language is necessary if the full usefulness of these meetings is to be attained. It is certain, however, that few busy professional men can afford the time to get that facility of expression called for in debate if any one of the national languages be chosen. One is forced to the conclusion that only an easy, exact, and therefore artificial language can be expected to fulfil the functions of an auxiliary language such that everyone could use it when communicating with foreigners. It follows from a knowledge of the formation and history of artificial languages that, in my opinion, the use of Esperanto is the only present solution of the problem under discussion. The ready communication of engineers with their clients and with each other irrespective of national linguistic differences.

Reply.

Mr. Gueritte wished to thank all present for the very kind way in which they had received his paper, and especially those who had taken part in the discussion. Most of the points necessitating reply had been dealt with by Mr. Mudie, the President of the British Esperanto Association, whose remarks carried greater weight than his own. There was only one point he would like to mention again, and that was the possibility of improvements in Esperanto. He quite believed that in course of time, as experience was gained, improvements might automatically introduce themselves into the language. The important thing, however, was not to be checked by theorists who advised that no practical use should be made of an international language until absolute perfection had been attained. Nothing was perfect in this world. Even the British Constitution had been said not to be perfect, but great things had been accomplished by putting it to practical use. They were practical men, and men of action ; let them not wait any longer for an ideally perfect idiom ; what had been offered to them had been proved by wide experience to be good for all practical purposes. Let them use it for the good of mankind at large.

6th April, 1914.

H. C. H. SHENTON, PRESIDENT,

IN THE CHAIR.

THE UTILISATION OF SOLAR ENERGY.

By A. S. E. ACKERMANN, B.Sc. (Engineering), A.C.G.I., M.Cons.E., A.M.I.C.E.

INTRODUCTION.

IN the history of the progress of the World, it has been a common occurrence for valuable scientific facts to be well known to the savants of the age and yet for such facts to remain in the laboratory or embryo stage for years before they have come to the general knowledge of the public, and have been adapted to commercial uses for the convenience and advancement of the human race. To mention only two cases: Hero of Alexandria, realised "the force of steam," as it has been called, when in the third century he constructed his engine (really a steam turbine!). The Marquis of Worcester took up the subject fourteen hundred years after, but it was not till the eighteenth century that Newcomen and Watt, and in the nineteenth century Stephenson, so improved the steam engine as to make it useful to man. The history of electricity is similar. Electricity was known to the ancients, but until the days of Clerk-Maxwell and Faraday its development was not rapid, and even then, others had to come after Faraday to apply successfully to commercial purposes the knowledge previously gained. In the intervening period, between the discovery of the facts and their early commercial applications, the number of people is legion who (with very little basis for their remarks) scoff at the possibility of the practical application of the discoveries of scientists. The matter is outside their personal experience, and when anything is beyond one's experience it is naturally somewhat hard to realise and to credit.

It is outside the experience of the vast majority of engineers even, that water may be caused to boil at a temperature of 212° F. *or more*, by the *unconcentrated* rays of the Sun! It was outside the author's experience in June, 1910, and as a consequence, at that time he felt very doubtful as to whether it were possible. Now, not only does he know it is possible, but it has been such a common experience during the past four years, that the sight of an 8-inch flange, on an 8-inch steam main, dancing as it continually allows the sun-produced steam to escape, no longer produces the mental effect it did at first. Similarly with

Early History. regard to the utilisation of sun-power, it has been known for centuries that by concentrating the Sun's rays, great heat can be produced, and this has been used for say cooking a steak, or boiling water, even under pressure, but it is a popular fallacy that Archimedes destroyed the fleet of Marcellus at Syracuse in 212 B.C. by means of mirrors reflecting the Sun's rays! The concentration of the rays has usually been done by parabolic reflectors of metal or silvered glass, but lenses have also been used. John Ericsson, whose name will ever be remembered and honoured as a most persistent pioneer in sun-power work, used many reflecting devices for concentrating the rays, and had a $2\frac{1}{2}$ horse-power sun-engine running more or less on practical lines in New York, in 1886. Other pioneers have been Féry, Millochau, Mouchot (one of the greatest) and Tellier in France; Guntner and Althaus in Germany; and Langley, Willsie, and Frank Shuman in the United States. It is the work of the last named with which the author has been associated, and that is described herein.

Solar Constant. One of the first questions that occur in considering the subject of solar energy is what is the available quantity of it. By solar energy in this connection we do not mean the total heat per minute given off by the Sun, but only the extremely small fraction of this which impinges on the outer surface of the Earth's atmosphere. The quantity of radiation falling perpendicularly on unit area at the outer surface of the atmosphere in unit time is called the *Solar constant* and has been determined experimentally by several scientists. Dr. S. P. Langley in 1881 obtained the value of 3·0 calories per square centimetre per min. During 1905-6 some 130 measurements were made at the Carnegie Institute on Mount Wilson (U.S.A.), which is 6,000 ft. high, and the mean of these is 2·02 calories per square centimetre per min. Between 1902 and 1907, 41 similar determinations were made at the Astrophysical Observatory at Washington, the mean of which is 2·06 calories per square centimetre per min. In 1908 Millochau and Féry experimented on the summit of Mt. Blanc (15,780 feet) and obtained the value 2·38. In 1909 Dr. Scheiner of the University of Potsdam, experimenting on a Swiss mountain 10,000 ft. high, found the value of the solar constant to be 2·31 calories per square cm. per minute. Prof. J. H. Poynting, F.R.S., in 1904 adopted the value 2·5 calories per square centimetre per minute. The author has used the value 2·05 calories per square centimetre per minute in many of the calculations that follow, and has since learned from Mr. C. G. Abbot, the director of the Astrophysical Observatory of the Smithsonian Institution, that their latest determinations give the value 1·93. As might have been expected the solar constant

varies slightly with the distance between the Earth and the Sun It has also been found by Mr. C. G. Abbot to vary from 3 to 5% in a period varying from 7 to 10 days. Incidentally it may be mentioned that by a simple calculation involving the solar constant we are able to estimate the temperature of the Sun and obtain 6,000°C. as the result.

Available heat supply from the Sun.

For practical use we need to know how much of the radiant energy of the Sun is reflected by our atmosphere, and how much of that which is not reflected is absorbed in passing through the atmosphere. There does not appear to be much information on this point, though about 50% of the whole is the figure given by some. Dr. P. Phillips states that, "in perfectly bright sunshine it is estimated that only three-fifths (60%) is transmitted." Mr. H. T. Wade in giving the Mt. Wilson and Washington results in October, 1908, stated that of the total quantity of radiation arriving at the outer surface of our atmosphere, 37% is reflected, 18% is absorbed by the atmosphere, and 45% reaches the Earth's solid surface. Mr. C. G. Abbot in Feb., 1913, gave 0·28 calorie per sq. cm. per min. as the heat reflected by our atmosphere. This means that 14·5% is reflected. Presently it will be seen that 70% is transmitted to the earth's surface. Hence 15·5% is absorbed by the atmosphere. It is the 70% with which engineers are concerned, for it represents the maximum quantity of heat available for transformation into mechanical energy, and hence corresponds with the calorific value of coal, or other fuel, and enables us to calculate the thermal efficiency of Sun-heat absorbers, *i.e.* the ratio of the heat usefully absorbed to the heat available for absorption. Bouguer and Lambert (independently) showed in 1760 that when a ray traverses a homogeneous transparent medium, the intensity E, after traversing any given thickness t of the medium, is given by the formula $E = E_0 a^t$ in which E_0 is the original intensity and a is a constant, called the coefficient of atmospheric transmission which represents the proportion transmitted by unit thickness. If z is the zenith distance (expressed as an angle) $E = E_0 a^{\sec. z.}$

The value of a at sea-level appears to be about 0·70.

Experiments made recently in the U.S.A. showed that the loss in passing through the lowest mile of atmosphere is even more (19·4%) than the entire loss (12·7%) due to the atmosphere above Mt. Wilson. The means of the results for the true *vertical* transmission of total solar radiation are as follows :—

At Washington	69·9%
On Mt. Wilson (6,000 ft.) ..	81·7%
On Mt. Whitney (14,500 ft.) ..	89·6%

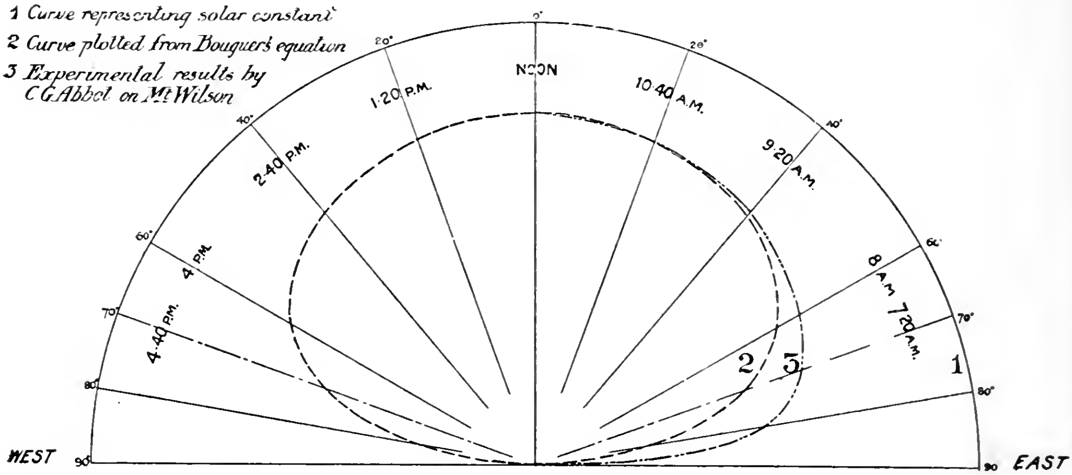


FIG. 1.

The percentage transmission varies with the wave-length of the radiation, being greater for the longer wave-lengths.

The author has not been able to find experimental results showing how much the total radiation (*i.e.* the combined radiation of all wave-lengths) is affected at sea level by the length of the path of the rays through the atmosphere, but Mr. C. G. Abbot in his work on *The Sun*, p. 297, gives a table of the transmissions at different zenith distances for radiation of many different wave-lengths, from which, and from the results just given, it would appear as if radiation having a wave-length of $0 \cdot 5\mu$ is transmitted in the same proportions as total radiation, consequently the following figures are given as being the probable percentage transmissions of total radiation at different zenith distances :—

Zenith distance.	0°	60°	70° 32′
Place.	Percentage transmission.		
Mt. Whitney (14,500 ft.) ...	90 .3	81 .5	73 .6
Mt. Wilson (6,000 ft.) ...	87 .3	76 .2	66 .5
Washington	70 .4	49 .6	34 .9

Mr. C. G. Abbot states (p. 284 *ibid*) that, " the maximum intensity of solar radiation, as measured near sea level at Washington when the Sun is not more than 45° from the zenith, usually ranges from 1·15 to 1·45 calories per square centimetre per minute on

cloudless days, depending on the clearness and dryness of the air." Taking the solar constant as 1·93 calories per square centimetre per minute, this means that the transmission varies there from 59% to 75%. The mean of 1·15 and 1·45 is 1·30. Hence the mean transmission at Washington is 67.3% for a range of 45° on each side of the zenith.

Applying Bouguer's formula and taking $z=22\frac{1}{2}°$ as the mean zenith distance between 0° and 45°, and $a=0·70$ we have

$$(0·70)^{1·082} = 0·679$$

That is, the mean transmission at Washington is 67·9% which agrees remarkably well with the mean (67·3%) of the figures given by Mr. Abbot for a zenith range of 45°E. to 45°W., and which appear to be experimental results. Using the same formula and taking $z=60°$ and $a=0·70$ we find the transmission is 49·0% which agrees very well with 49·6 the figure for 60° in the table just given.

Taking 1·93 cals. per sq. cm. per min. as the value of the solar constant, and 60% as the average percentage arriving at the Earth's solid crust, we have 60% of 1·93 = 1·160 cal. per sq. cm. per min. as the average available heat. Naturally this available heat is much affected by clouds, and even when the sky is perfectly clear the amount available is affected by the hygrometric state of the atmosphere, as will be seen from the results which were obtained in the experiments herein recorded. Thanks to our so-called "system" of British units (which we must use as this paper is for English readers) the transformation of calories per square centimetre per minute into B.T.U. per square foot per hour is laborious. When done we find that 1·160 calories per sq. cm. per min. = 257 B.T.U. per square foot per hour, which is the maximum average amount of heat that a perfect Sun-heat absorber could absorb. 257 B.T.U. per sq. foot per hour $= \frac{257 \times 4840 \times 9}{60 \times 42·5} = 4,440$ H.P. per acre, a figure which has naturally excited the cupidity of inventors and others in the past, and for the sake of progress (especially in view of the rapidly decreasing quantity of coal) it is to be hoped it will continue to do so in the future.

John Ericsson, the great inventor who worked at the problem of the utilisation of solar energy, wrote as follows in 1876, "Let us estimate the power that would result from utilising the solar heat on a strip of land a single mile in width along the rainless western coast of America, the Southern coast of the Mediterranean, both sides of the alluvial plain of the Nile in Upper Egypt, both sides of the Euphrates and Tigris for a distance of 400 miles above the Persian Gulf, and, finally, a strip one mile wide along the rainless portions of the shores of the Red Sea." He then goes on to show that, allowing 100 sq. ft. per

horse-power, the aforesaid area could keep 22,300,000 solar engines (each of 100 B.H.P.) in constant operation nine hours a day!! With regard to this the author has only to remark that his experience shows that about 250 sq. ft. of sunshine are required per B.H.P. But even this would allow for nearly 10 million engines each of 100 B.H.P.!

A peep into the future!

"Due consideration cannot fail to convince us (says Ericsson) that the rapid exhaustion of the European coal fields will soon cause great changes with reference to international relations in favour of those countries which are in possession of continuous sun-power. Upper Egypt for instance, will, in the course of a few centuries, derive signal advantage and attain a high political position on account of her perpetual sunshine and the consequent command of unlimited motive force. The time will come when Europe must stop her mills for want of coal. Upper Egypt, then, with her never-ceasing sun-power, will invite the European manufacturer to remove his machinery and erect his mills on the firm ground along the sides of the alluvial plain of the Nile, where an amount of motive power may be obtained *many times greater than that now employed by all the manufactories of Europe.*"

Dr. S. P. Langley in his book entitled, *The New Astronomy*, p. 116, says, "Whoever finds a way to make industrially useful the vast Sun-power now wasted on the deserts of North Africa or the shores of the Red Sea, will effect a greater change in Man's affairs than any conqueror in history has done, for he will once more people those waste places with the life that swarmed there in the best days of Carthage and of old Egypt, but under another civilisation, where Man shall no longer worship the Sun as a god, but shall have learnt to make it his servant." While the late Prof. R. H. Thurston writing in *Cassier's Magazine* for August, 1901, stated that, "Prof. Leslie, when State geologist of Pennsylvania, and the late Mr. Eckley B. Cox, estimated the probable life of the coal supplies of that State, at the present rate of consumption and acceleration, to be something like a century, and the close of the twentieth century will be very likely to see an end of such manufactures in that State as depend upon cheap fuel and proximity to the coal deposits. In Great Britain the case is probably vastly more serious than in the United States, for there the coal beds are far more restricted in area, and in many localities are already extensively depleted, with prices rising as a consequence."

The plant used for the experiments that are herein recorded was considerably improved from time to time, and embodied three distinct types of absorber, and though the type of engine for utilising the steam from the absorber was not altered, yet

the design of the valves was changed, and the important novelty was tried of having two pistons in one cylinder and rigidly attached to the same piston-rod. In some of the experiments the inter-piston space was connected with the boiler.

In some still earlier experiments with the engine (with which experiments unfortunately the author was not connected) it was shown by Mr. Shuman that to a very large extent the material of which a cylinder is made does not effect cylinder condensation, this being due to the film of water on the cylinder walls. Moreover the author never had an opportunity of testing the first form of absorber. With these exceptions perhaps it may be stated here that the whole of the arrangements for the tests were (with one or two exceptions in America) designed by the author (and met with the approval of his colleague, Mr. C. T. Walrond, A.M.I.C.E., A.M.I.E.E.) and that he was responsible for the methods adopted and the nature of each experiment made. Needless to say he would have made many more experiments, but the work was being done for enterprising clients whose commercial needs had to be kept in view.* This statement is made thus clearly lest some sceptics might think the inventor possibly influenced the results in some manner. In nearly all cases too the author had his own staff of assistants, and when they were not entirely his, his own men took the important readings, and all were carefully checked. The inventor, Mr. Frank Shuman, afforded the author every facility for the work (for which he takes this opportunity of thanking him), and everything was thoroughly examined.

THE SUN-HEAT ABSORBERS.

The 1907 *Absorber.*

Shuman's first Sun-heat absorber of any size consisted of a number of parallel horizontal black pipes containing ether, placed on the ground in a shallow box, about 20ft. × 60 ft. × 18 ins. deep, containing water with a layer of melted paraffin wax on it and having a glass top. By this means the ether was caused to boil, and produced vapour sufficient in quantity and pressure to drive a small vertical reciprocating engine. The exhaust ether vapour was condensed and the fluid ether returned to the " boiler."

This Sun-power plant, which was constructed in 1907, was made to drive a small centrifugal pump so as to give some idea of the power produced, and it is said that the plant worked, when the sunshine was bright, even when the atmospheric temperature was below 32°F.

* The clients were the Shuman Engine Syndicate, Ltd., and the Sun Power Company (Eastern Hemisphere) Ltd., to both of which companies the author and Mr. C. T. Walrond were joint Consulting Engineers. The author wishes to thank them for kindly giving him permission to publish technical information concerning the plants.

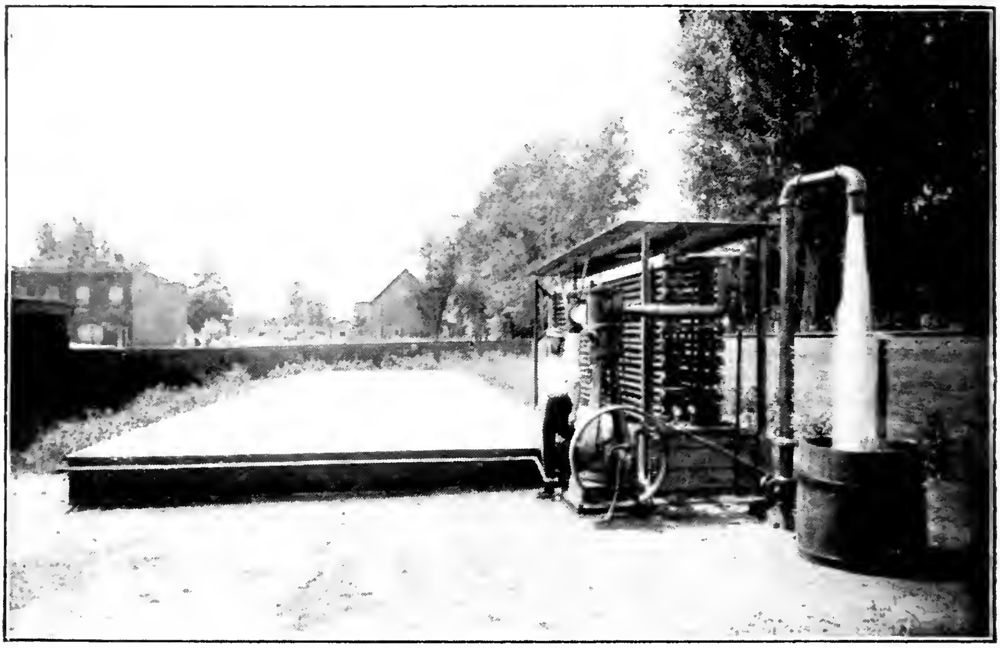


FIG. 2.
FIRST SHUMAN SUN-HEAT ABSORBER; 1907.

The 1910 *Absorber.*

The next design of absorber was made and erected at Tacony, Philadelphia, U.S.A., in 1910, and was quite different in principle. Only water was used and this was contained in a lamellar boiler made of two thin tinned-copper sheets, each 6 ft. long by 2 ft. 6 in. wide, with a space of only $\frac{3}{16}$ inch between them for the water. Cold water was admitted at the lower edge at one corner and the steam pipe was attached to the upper edge at the opposite corner. The boiler was contained in a wooden box, the overall dimensions of which were 2 ft. 9 in. $\times$ 6 ft. 3 in. $\times$ 6 in. deep. The top of the box was made of two sheets of ordinary window glass $\frac{3}{32}$ in. thick with a 1 in. air-space between the two sheets, and another air-space of 1 in. between the inner sheet of glass and the boiler. At the back of the boiler there was an air-space of $\frac{3}{8}$ in. in communication with the air-space between the boiler and the inner or second sheet of glass. At the back of the $\frac{3}{8}$ in. air-space there was a 2-inch layer of "lith" (*i.e.* jute waste mixed with mineral wool) and then the wooden board 1 inch thick forming the bottom of the box. Everything was painted a dull black and the whole made as nearly air-tight as possible. Along the bottom of the box and in the centre of its length there were lugs or hinges by which it was pivoted to its triangular angle-steel stand. There were also two perforated links by which the inclination of the box to the horizontal could be altered at will. The width of the absorber

was placed East and West, and the inclination was adjusted weekly so that the glass top was perpendicular to the Sun's rays at noon. No attempt was made to keep the surface facing the Sun throughout the day.

Relative position of Absorber.

In the position in which the Absorber was when first examined, the lower bottom edge was 1 ft. 8 in. and the upper bottom edge 4 ft. 5 in. from the ground level. The ground under and immediately surrounding the Absorber was bare clay. The three boundaries near the Absorber were formed of boards painted dark green, 5 ft. 6 in. high, with a fair quantity of green creepers growing over them. The boundary, which was 72 ft. away, was the red brick wall (about 12 ft. high) of Mr. Shuman's offices. Except for these offices there was no building within 200 ft. of the Absorber, though there were a few trees some distance off.

Principle on which the Absorber acts.

From the foregoing description it will be seen that the construction was extremely simple. There were no mirrors, reflectors, or lenses of any kind and no attempt was made to deflect, divert, or concentrate the Sun's rays. The whole effect (which is scarcely credible until it has been seen and experimented with) was brought about by the use of the properties of glass, which readily permit the Sun's radiation to pass through it, but will not conduct the sensible heat from the hot air on the other side, glass being a bad conductor of heat. The air spaces also acted as efficient heat insulators. The radiation from the Sun is not converted into heat until it impinges on something more substantial than air (hence the extreme cold of the upper regions of the Earth's atmosphere). A dull black surface is the best known surface for absorbing the radiation from the Sun and converting it into heat. Thus the radiation penetrated the glass, struck the dull black boiler and was converted into heat. Much of this would then have escaped by convection and conduction had it not been for the air spaces and glass. In the tropics, where the surrounding air would be at a higher temperature, the loss by conduction and radiation would be less.

TRIALS.

Trials of the 1910 Absorber.

The FIRST TRIAL lasted two hours, from 11.45 a.m to 1.45 p.m. on 21st August, 1910, but except for the first 25 minutes, the conditions were so extremely variable, owing to the clouds passing between the Sun and the Absorber, that the results are given as means and totals based on the first 25 minutes only. At the end of the two hours, 70 per cent. of the sky was covered with dark cumulus clouds. The velocity of the wind averaged about 5 miles per hour.

	°F.
Temp. in top space of lower edge of Absorber	165·3
,, ,, bottom ,, ,, ,, ,, ,, ,,	194·8
,, ,, top ,, ,, upper ,, ,, ,,	171·3
,, ,, bottom ,, ,, ,, ,, ,, ,,	206·4
,, ,, Sun's rays (ordinary mercurial therm.)	80·7
,, ,, shade, dry bulb thermom.	78·4
,, ,, ,, wet ,, ,, ...	69·4
Humidity	63 per cent.

Total quantity of steam (evaporated from 95°F. and at a temperature of 212°F.) produced by the Absorber in 25 mins. .. .. .. =0·403 lb.

Total quantity of heat given to the steam .. =1047 B.T.U. per hour.

Useful heat absorbed per sq. foot of glass surface of Absorber .. .. = 68·8 B.T.U. per hour.

Rate of Absorption of heat.

During two periods each of 5 minutes, namely from 11.50—11.55 a.m., and 0.50 to 0.55 p.m., the rate was 72·4 B.T.U. per sq. ft. per hour. This was the maximum rate obtained during the test.

The effect of cloud passing between the Sun and the Absorber was almost instantly to reduce the quantity of steam produced, and a very short period of cloud was sufficient to stop the production of steam almost entirely. On the cloud disappearing, the reverse effect was quick, but not so quick as the first.

Size of Absorber required.

Taking the maximum rate of 72·4 B.T.U. per square foot per hour, and taking the Shuman low pressure engine (1910 design) when it was working most economically (*i.e.* during Trial I., *vide* results on p. 129) it required 477 B.T.U. per brake horse-power per min. or 28,620 B.T.U. per brake horse-power hour, or 846,500 B.T.U. per hour for the engine when developing 29·6 B.H.P. Therefore the engine in Trial I. would have required 11,680 sq. feet of Absorber surface (395 sq. ft. per B.H.P.) to have supplied it with steam, exclusive of that required for the air pump.

In the SECOND TRIAL of the Absorber the conditions were much more satisfactory, as throughout the day the sky was clear and there was no wind. The reasons for making the second trial were, (*a*) because the conditions of the sky was so unfavourable in the first test, (*b*) to show the effect of a lower temperature in the Sun's rays, this temperature being about 9°F. lower than in the first test. The steam-producing trial lasted one hour from 11.40 a.m. to 0.40 p.m., on 27th August, 1910. The following are the means and totals for the whole period :—

		°F.
Temp. in	top space of lower edge of Absorber	161·9
,, ,,	bottom ,, ,, ,, ,, ,, ,,	187·2
,, ,,	top ,, ,, upper ,, ,, ,,	172·7
,, ,,	bottom ,, ,, ,, ,, ,, ,,	210·2
,, ,,	Sun's rays (ordinary mercurial therm.)	72·4
,, ,,	shade, dry bulb thermom.	70·0
,, ,,	,, wet ,, ,, ...	62·5
Humidity	.. ..	64 per cent.
Total quantity of steam produced during the hour		0·881 lb.
Total quantity of heat given to the steam	..	=955 B.T.U.
Useful heat absorbed per sq. foot of glass	..	=59·2 B.T.U. per hour.

The whole of the temperatures were remarkably steady, except for the rise of temperature of the lower portion of the Absorber. This had been cooled by suddenly letting in water at about 73°F. shortly before the test started. The quantity of condensed steam collected never exceeded 37 cubic centimetres in 5 mins. nor was it ever less than 32 c.c. in the same period.

In the THIRD TRIAL of the Absorber, made the same day as the second and under the same favourable conditions of the sky, no steam was produced, the trial being made to determine the quantity of water that it was capable of raising from the feed temperature to about 184°F. (the temperature of steam at a pressure of 8 lb. per sq. in. absolute). The result was that 14·7 lb. of water at 72·9°F. were heated to 181·5° F. during the hour (1.55 p.m. to 2.55 p.m.) that the trial lasted. This is equivalent to a rate of absorption of heat of 98·9 B.T.U. per sq. foot of glass per hour, which is about 67% more than the 59·2 B.T.U. absorbed in the morning of the same day when *steam* at 212°F. was being produced. In the afternoon, too, the angle made by the Sun's rays on the Absorber was less satisfactory. It must not, however, be assumed that if *steam* at 184°F. had been produced (there were no arrangements for producing steam at this temperature) the same rate of heat absorption would have been maintained. When steam is formed the bubbles of steam adhere to the surface of the lamellar boiler and act as non-conductors of heat, thus reducing the rate of absorption.

The Sun-Heat Absorber of 1911.

The author arrived at Tacony, Philadelphia, on Saturday, 22nd July, 1911, and left on Wednesday, 30th August, 1911, and during that period he had every facility for studying the Absorber under different conditions and for investigating its construction, which was completed while he was there.

Construction. The essential features were the same as those of the small model unit just described, but whereas in the old design there was absolutely no concen-

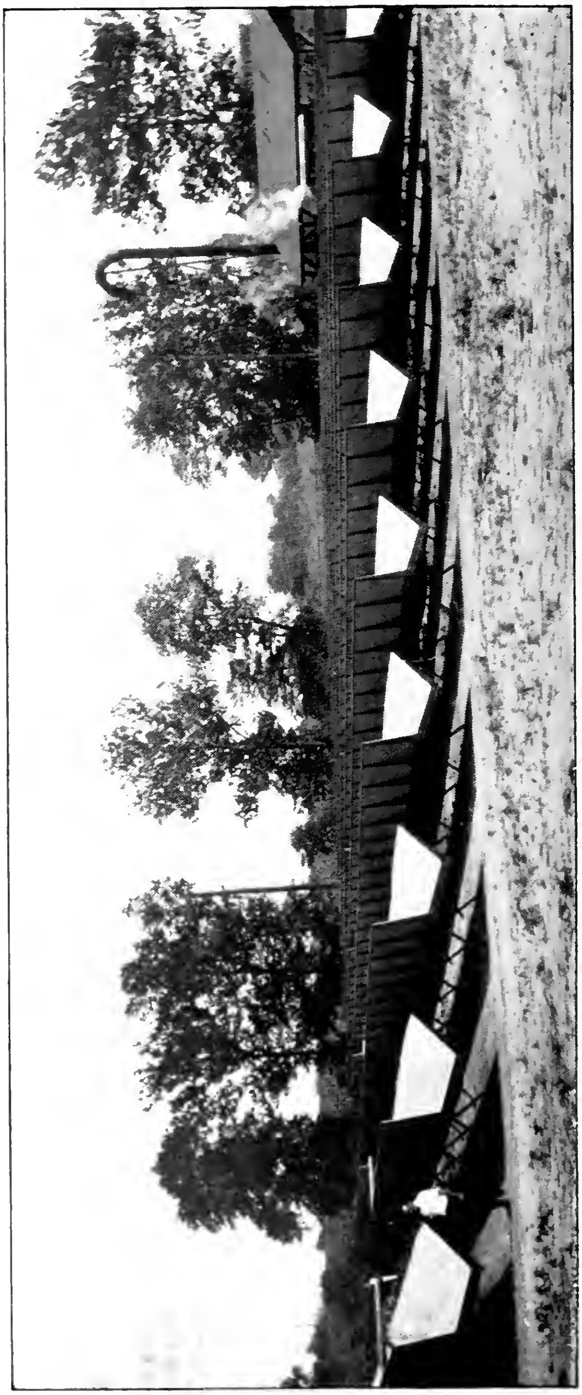


Fig. 3.

General View, from the West, of the Tacony Absorber, 1911.

tration of the Sun's rays, in the 1911 type there was a concentration of two to one by *plane* glass mirrors. By this is meant that the rays falling normally on an area of, say, 200 sq. ft., were collected and received by a boiler area of 100 sq. ft. Each cell consisted of a lamellar boiler nearly a yard square and about $\frac{1}{4}$ inch thick with a water space of about $\frac{1}{8}$ inch thick. The lamellar boiler was made of tin-plate (*i.e.* sheet iron with a coating of tin), and was supported in a wooden frame. In front of it were two sheets of ordinary window glass with an air space of one inch between them. Between the boiler and the lower or inner glass there was also an inch of space and another underneath the boiler, then a $\frac{1}{4}$ inch mill-board sheet, two inches of cork-dust (in place of the "lith" used in the 1910 design), and lastly $\frac{3}{8}$ of an inch of mill-board (in place of wood) to support the cork-dust. Twenty-two such cells, placed in line, edge to edge, form one section, which was thus 22 yards long by a yard wide. A small brass pipe ran along the bottom edges of the cells to supply the feedwater, and along the top was a larger brass pipe for carrying off the steam. Both these pipes and the whole boiler were painted dull black so that they all acted as heat-absorbing surfaces. There were 26 of these sections arranged in two equal groups, one being on each side of the 8-inch main steam pipe, and the sections being at right angles to the pipe which was placed "North and South." Along the ground and under the steam main was the iron feedwater main connected to the sections by small lead pipes. The iron steam main was connected to the steam pipes of the sections also by lead pipes, and the flexibility of all these lead pipes was relied on for the small amount of movement necessary to permit the position of the sections of the Absorber being adjusted, say once every three weeks, to suit the angle which the Sun's rays make with the surface of the Earth at noon at different seasons of the year. Each cell had two fixed silvered glass mirrors, each one yard square, attached to its bottom and top edges respectively, and making angles of 120° with the plane of the boiler. The top edges of the mirrors were thus 6 ft. apart, and this width of radiation was reflected and received by the cells at the bottom, which were only 3 ft. wide. Hence the concentration of two to one.

Area of sunshine collected.

The total area of radiation collected was 10,296 sq. ft., while the area of land occupied by the whole Absorber and steam main, including all gangways, measured 126 ft. by 142 ft., or less than $\frac{2}{5}$ of an acre. The gangways were very wide, so that even that area might have been reduced with a consequent saving of steam and water mains, as well as of land.

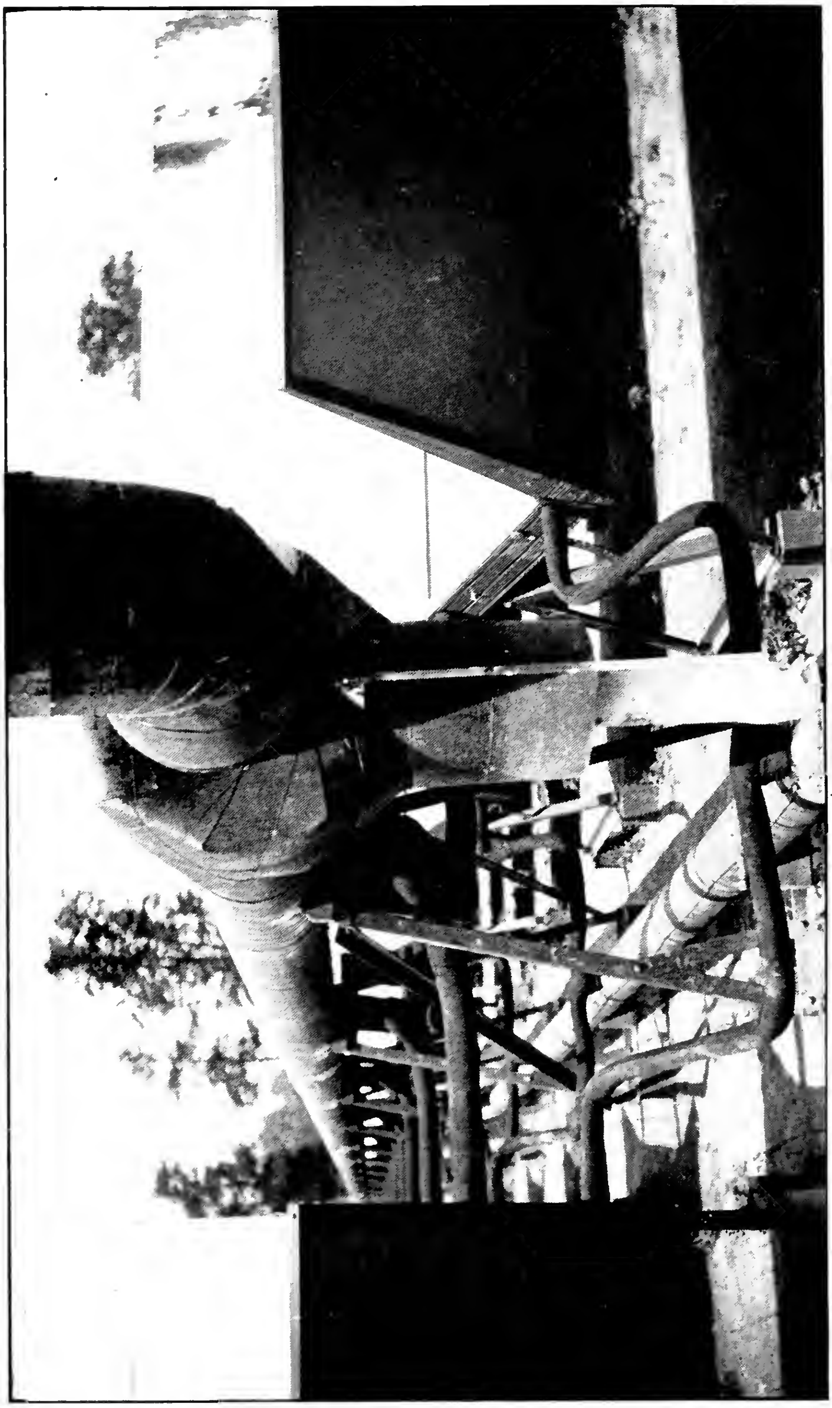


Fig. 4.

Tacony Absorber, 1911. Steam and Water Pipes and their Branches.

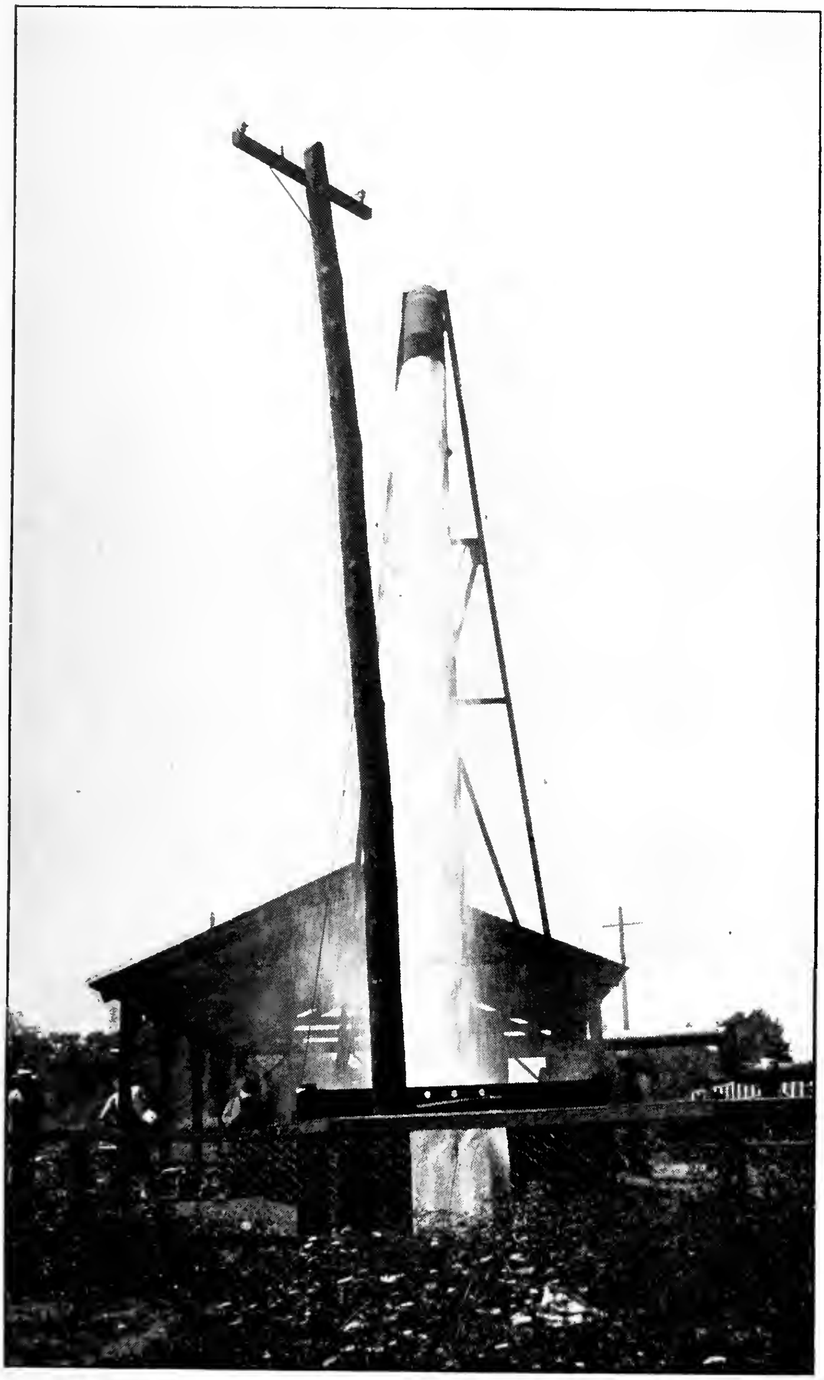


Fig. 5.

Trial of Tacony Absorber on 10th August, 1911.
Lift 33 feet.

Trials of the 1911 *Absorber.*

A series of three trials of the Absorber was made on the 10th, 11th, and 12th of August, 1911, but owing to work which was being done on the engine, these trials did not start as early in the morning as they might have done, for steam at $\frac{1}{2}$ lb. sq. in. *above* atmospheric pressure was blowing off for $1\frac{1}{4}$ hours, $2\frac{1}{2}$ hours, and 1 hour respectively before the trials started, which was at 11.15 a.m., 0.16 p.m., and 11.17 a.m. respectively. The trials lasted 5 hours, 1 hour, and 4 hours, ending at 4.18 p.m., 1.16 p.m., and 3.17 p.m. respectively.

For details of the trials see p. 97.

Rate of Absorption of heat.

Considering the first and best hour of the first trial we find that the rate of absorption of useful heat was 88 British Thermal Units per hour per sq. ft. of solar radiation collected. This was certainly an excellent result, especially for the first Absorber on commercial lines. This rate too was kept up for an hour, whereas in 1910 the maximum rate of 72·4 B.T.U. per sq. ft. per hour of the single cell was maintained for only 5 *minutes!* 88 B.T.U. is 21·6% better than 72·4 B.T.U.

Horse power of the 1911 *plant.*

It was extremely unfortunate that the power of the engine, when using the Sun-steam, could not be measured, as no satisfactory arrangements had been made for the purpose, but utilising the results the author obtained when testing a similar engine in 1910, it is found that the following power might have been produced during the first trial :—

During the 1st hour	26·8 B.H.P.
,, ,, 2nd ,,	24·5 ,,
,, ,, 3rd ,,	19·6 ,,
,, ,, 4th ,,	13·2 ,,
,, ,, 5th ,,	8·6 ,,

The mean of these is 18·54 B.H.P. for 5 hours.

As steam at $\frac{1}{2}$ lb. per sq. inch by gauge was blowing off more than an hour before the trials began, and as it is reasonable to suppose that the Absorber would have produced nearly as much steam before noon as after, we shall probably not be far wrong if we assume that the following additional results might have been attained if (as explained before) the engine could have been started earlier.

8.16 a.m.—9.16 a.m., 385 lb. of steam at 6·4 lb. sq. in. abs., equivalent to 7.8 B.H.P.

9.16 a.m.—10.16 a.m., 423 lb. of steam at 12·2 lb. sq. in. abs., equivalent to 11.9 B.H.P.

10.16 a.m.—11.16 a.m., 615 lb. of steam at 12·5 lb. sq. in. abs., equivalent to 17·7 B.H.P.

Trial.	1911.	Period.	Weight of steam produced lb.	Mean Pressure of steam. lb. sq. in. abs.	Mean Temperature of Feed-water. °F.	Rate of absorption per sq. ft. of radiation collected. B.T.U. per hour.	Thermal Efficiency of the Absorber. *	Brake horse-power.
a.	Aug. 10th.	11.16 a.m. to 0.15 p.m.	816.4	14.2	76.5	88.0	43.15%	26.8
b.	,,	0.15 to 1.15 p.m.	803.1	13.3	76.3	86.6	—	24.5
c.	,,	1.15 to 2.14 p.m.	682.8	12.5	76.0	73.5	—	19.6
d.	,,	2.14 to 3.17 p.m.	469.8	12.2	76.5	50.6	—	13.2
e.	,,	3.17 to 4.18 p.m.	425.6	6.4	76.3	45.3	—	8.6
	Total ...	5 hours.	3197.7	Mean 11.3	Mean 76.4	Mean 68.6	Mean 33.64%	Mean 18.54
f.	Aug. 11th.	0.16 to 1.16 p.m.	631.6	13.3	77.6	66.1	—	19.3
g.	Aug. 12th.	11.17 a.m. to 0.17 p.m.	765.6	12.3	77.5	82.0	—	21.9
h.	,,	0.17 to 1.18 p.m.	795.1	12.8	78.0	85.1	41.75	23.5
j.	,,	1.18 to 2.17 p.m.	649.4	10.6	78.3	69.5	—	16.7
k.	,,	2.17 to 3.17 p.m.	501.6	11.5	79.0	53.8	—	13.6
	Total ...	4 hours.	2711.7	Mean 11.8	Mean 78.0	Mean 72.5	Mean 35.54	Mean 18·93

* Based on 2·05 calories per sq. cm. per min. as the value of the solar constant, and a mean coefficient of atmospheric transmission of 45%. For explanation and later values, vide p. 118.

Hence, while the equivalent mean B.H.P. was actually 18·54 for the five hours, it is probable it might very well have been 16·26 for eight hours. It is hardly necessary to state that the powers thus attained are several fold greater than anything that had ever been obtained before by means of Sun-power.

Diurnal variation of steam production.

From these results we see clearly the great variation in the power that can be obtained from the Sun at different times of the day, when a fixed type of absorber is used. For example, in the first trial, the power developed during the fifth and last hour (3.17 to 4.18 p.m.) was only 8·6 B.H.P., *i.e.*, only 32·1% of what it was (26·8) during the first and best hour (11.16 a.m. to 0.15 p.m.). This decrease in power is due to several causes. First, the actual quantity of steam produced is less (52·2% less); secondly, the pressure is less (45% less); and lastly when the pressure is less the engine naturally requires a greater quantity of steam per horse-power hour, as steam of a low pressure is less valuable than that of a higher pressure, though its value is not in direct proportion to its pressure.

For most manufacturing processes it would be distinctly inconvenient to have such a variation in the power supply, though the fact that it would (in suitable situations) be a steady rise and fall daily would somewhat mitigate the trouble, as it might be possible to arrange for the heavy machinery to run only during the mid-day hours. It means also that the size of the engine would have to be large enough to take the maximum rate of production of steam, though this lasts for only three hours out of 24. Fortunately the objections to the variation of the power scarcely apply in the case of irrigation, unless the supply of water is small, or has to be pumped through pipes. In the former case there would not be enough water to be pumped during the period of maximum power. In the latter, the expense of the larger mains would be a consideration. Partial storage of the water would mitigate these evils, but with an addition to the cost.

Absorber Difficulties.

The possible evil effects of sand are two:—(1) It may lodge on the absorber and thus prevent the Sun's radiation from gaining admission. (2) It may scour the surface of the glass and turn it into "ground-glass," which again would probably stop most of the solar radiation. There are no experimental data, but it seems inevitable that even a small quantity of dust on the mirrors and plain glass must have a detrimental effect.

With regard to wind, on only one day during the author's visit to Tacony in 1911 was there a really strong wind, and this was on Friday, 18th August, when he was at Wissinoming, 2 miles from the Absorber. If the wind on the Absorber was

anything like what it was at Wissinoming, then it stood remarkably well. The Absorber was inspected the same evening to see if any damage had been done, but none had been.

Improvements.

In reporting on the 1911 design the author stated that he considered the water space in the lamellar boilers should be at least doubled, for two reasons:—(1) That there might be a larger body of hot water upon which to draw for steam during the passage of a cloud over the Sun, or during a temporary increase of load on the engine. It would not do to feed the boilers more rapidly at such times, as the feed is comparatively cool. What was wanted was a quantity of water *at the temperature of the steam*, so that on a slight reduction of the steam pressure (as the engine used the steam) this water would flash into steam and keep the engine going. (2) That there might be more room for scale. With a very small water space, a very little scale would render the boilers almost useless, and it was improbable that the formation of scale could be entirely prevented. It would be equally necessary to keep oil out of the boilers. If the boilers were made of copper there would be very little difficulty in "dishing" the sheets more so as to double the volume of water. Other possible improvements which he suggested were that the lower edges of the mirrors might be kept about one inch above the plain glass so as to allow sand to blow off if it should get on. Also that the mirrors might be made with hinges at their bottom edges, so that in the case of a severe hailstorm they could be folded down and on top of the boiler portions, thus protecting both the mirrors and the plain glass. This would mean that the backs of half the mirrors would need some protection against hail.

The Absorber of 1913.

The author (who was accompanied by Mr. G. W. Hilditch, A.M.I.C.E., as his chief assistant) arrived in Egypt on 8th July, 1913, and left on 1st September. During this period he superintended the tuning up of the engine and its auxiliaries, set its valves, measured up the whole plant, made all the arrangements for the tests, tested the plant for steam and air tightness, determined the slip of the irrigation pump, took levels to determine the suction and delivery heads, prepared for the rising of the Nile so that the lift could be quickly determined whatever the depth and width of the river, calibrated the testing plant, made the 35 trials herein recorded, worked out the results, and wrote the report. The time taken to do this may seem long, but it must be remembered that work of this nature is seldom done without many practical difficulties, besides which the author was dependent almost entirely on native labour, and had the addi-

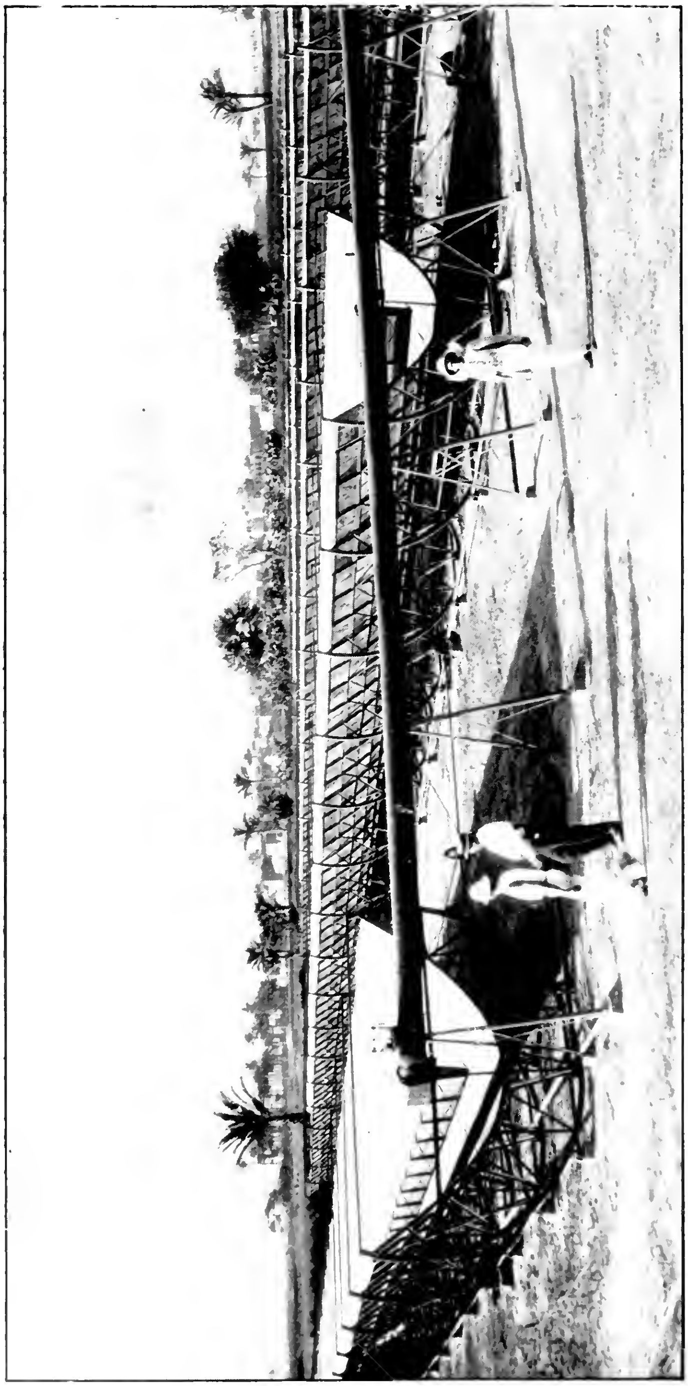


Fig. 6.

General View from the South of Meadi Absorber, 1913.

tional brakes of the language and the weather. The temperature varied from 100 to 106° F. in the shade. (At Luxor it was 100° F. at midnight in August !)

Prof. Boys' Improvements of the Absorber.

Before beginning the description of the 1913 Absorber, it should be recorded that in December, 1911, our clients asked us to select and invite some distinguished physicist to join us. We therefore presented Prof. C. V. Boys, F.R.S., with copies of all the reports which had been made to date, and having studied these he consented to act, and almost immediately proposed a vital alteration in the design of the Absorber. This at once received our hearty support and that of the directors. More important still, the inventor, Mr. Shuman, who was in America at the time, also approved, and he set to work to have an absorber made embodying Prof. Boys' improvement. Originally it had been intended to send the 1911 Absorber from Tacony to Egypt, but now it was decided to scrap this Absorber, and to build a Shuman-Boys one for Egypt. This proved a very wise decision, though it precluded the determination of the effect of different climatic conditions on the steaming capacity of the 1911 (Tacony) Absorber.

Construction of the Shuman-Boys' Absorber of 1913.

The construction of the Shuman-Boys Sun-Heat Absorber at Meadi is entirely different from that of the Shuman Absorber which was at Tacony in 1911, and which has been described herein. The Absorber at Meadi consists of five sections, each 205 feet long and 13 ft. 5 ins. wide between the edges of the mirrors. The cross section of each of the five sections is a parabola. Hence the mirror portion may be described briefly as five large parabolic channels. The mirrors are of flat glass $\frac{1}{16}$in. thick, silvered, coated with shellac, and painted, cut to various sizes from 18 inches square downwards, so as to fit round the parabola. They are carried on a light framework of painted steel, which in turn is supported at intervals of 12 feet by crescent-shaped, painted steel lattice frames, the outer curve of each of which is a circular arc rather more than a semicircle in length. The outer members of the crescent frames rest at the bottom on small wheels. Each also has a circular rack for a portion of the length of the arc, and geared with this rack is a small pinion which is driven by a system of tubular shafting, thus causing the parabolic mirrors to rotate. The five 205 ft. sections are placed with their major axes North and South. To receive the morning Sun they are heeled over to the East and move automatically very slowly from that position to the West so as to follow the Sun.

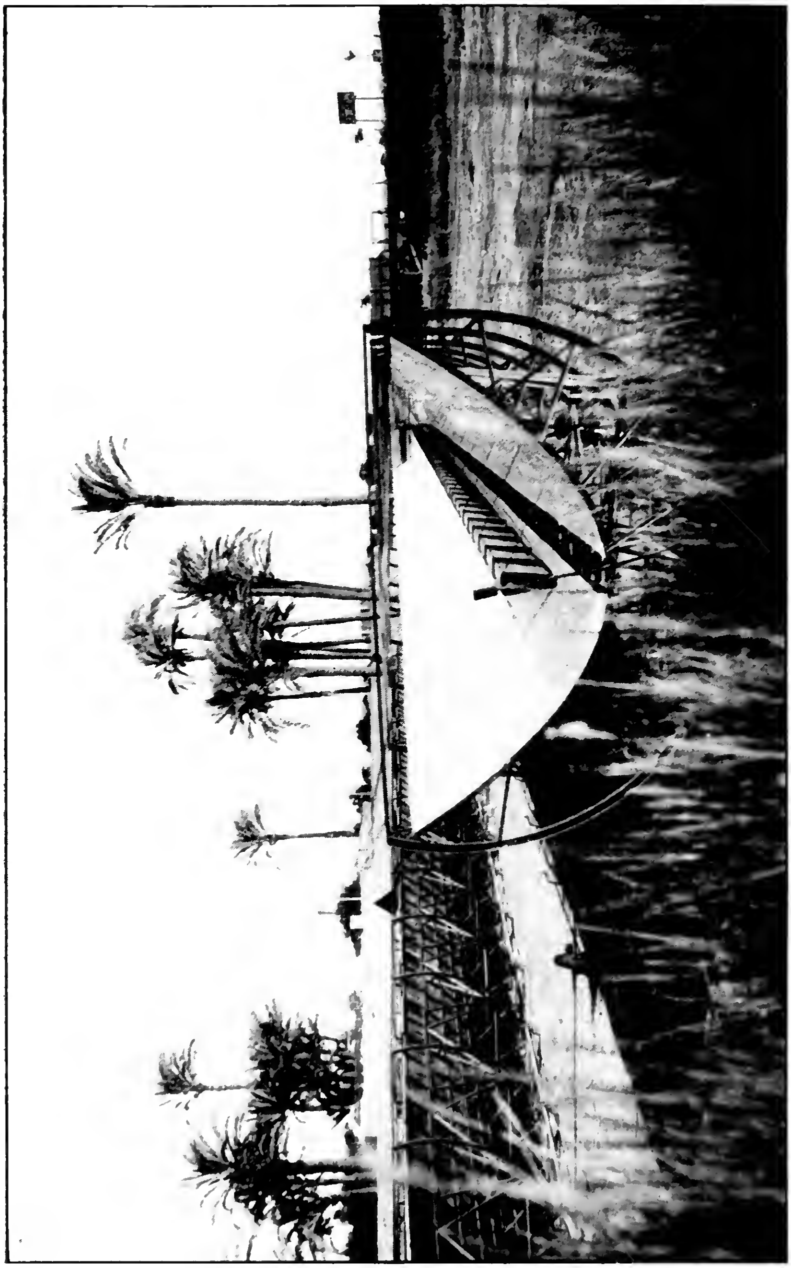


Fig. 7.

Meadi Absorber, 1913. One Section of the Absorber from the North.

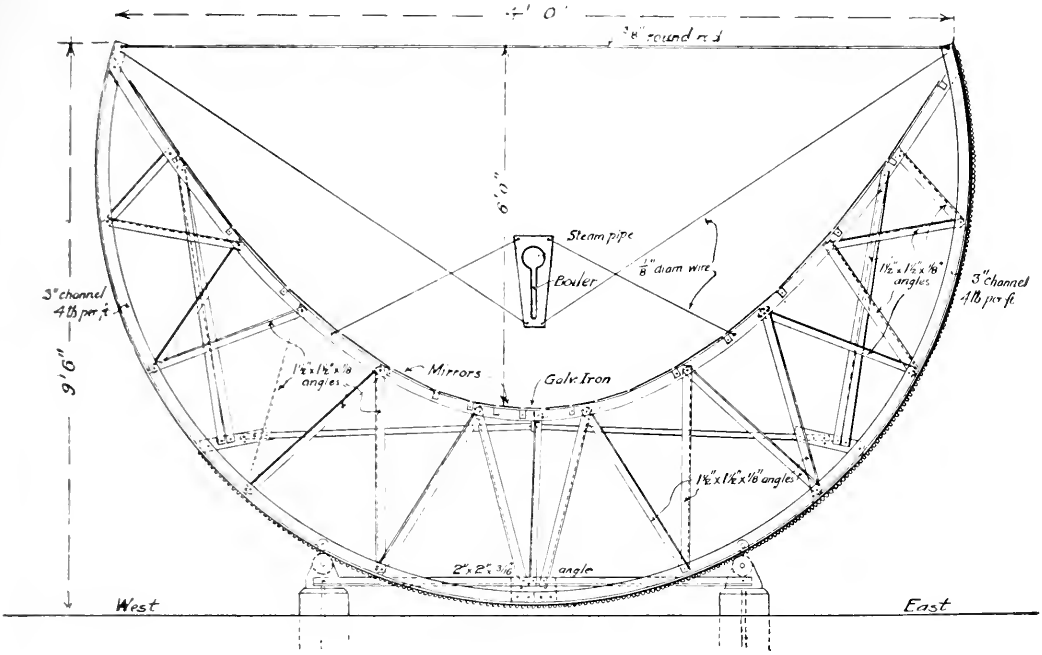
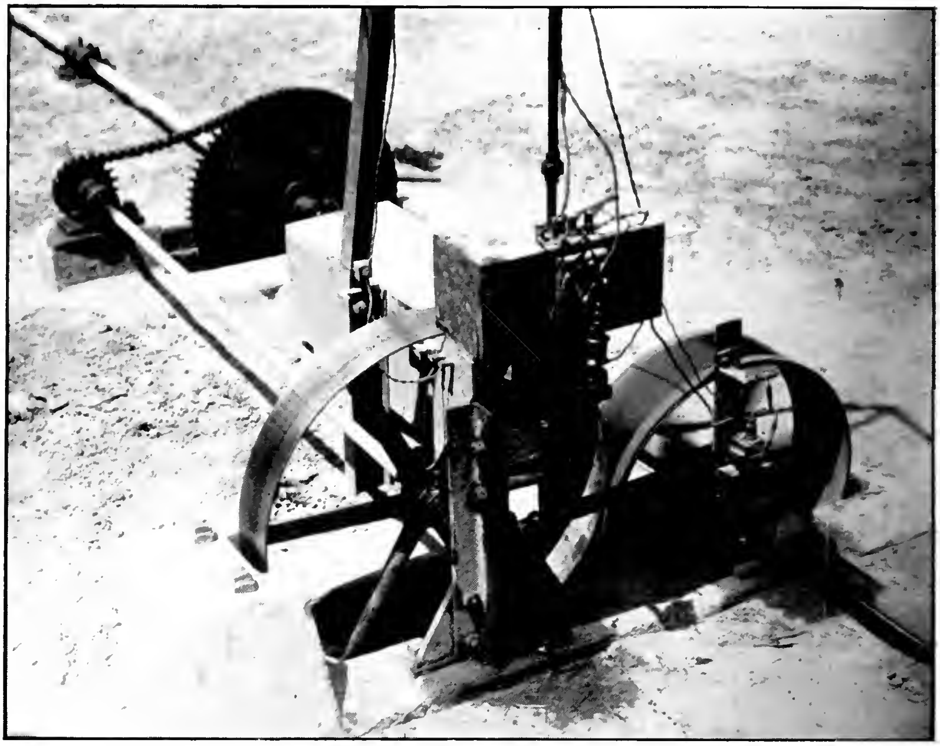


FIG. 8.
CRESCENT FRAME OF MEADI ABSORBER.

Automatic Control.

This automatic movement is controlled by a small and simple thermostat of three fingers, each consisting of a thin plate of brass underneath and a plate of vulcanite on top. In the working position two iron bands, each one inch wide, cast their shadows on the two outer fingers, leaving the middle one in the sunshine. When the shadows get off, or even partly off, the outer fingers, the latter bend down and close an electric circuit which includes a few Leclanché cells. The current magnetically moves the slide valve of a $2\frac{1}{2}$ in. $\times$ $2\frac{1}{2}$ in. single-acting vertical piston, and puts the cylinder (in which the piston works) into communication with the vacuum in the condenser of the engine. The piston is then "sucked" up, and its piston-rod being attached to a lever pulls up the latter, thus bringing a constantly rotating 18 in. pulley (driven by the engine) into contact with another 18 in. pulley, covered with leather. The second pulley is thus driven by friction and in turn drives the tubular shafting which causes the mirrors to rotate. The movement of the lever also breaks the electric circuit, which has done its work of moving the slide-valve. When sufficient rotation has taken place to bring the two outer fingers of the thermostat into the shadows again, another electric circuit is closed (by the outer fingers bending up and the middle one down) which magnetically moves the slide-valve in the opposite direction to that caused by the first circuit, thus



G. W. Hilditch. *Photo.*

FIG. 9.

MEADI ABSORBER, 1913.

FRICTION CLUTCH OF THE ROTATING GEAR, OPERATED BY THE THERMOSTAT.

admitting atmospheric air to the cylinder. The piston then falls and the friction pulleys are thrown out of contact, thus stopping the rotation of the mirrors.

The Boilers. The steam boiler is rigidly suspended at the focus of the mirrors, its cross-section being formed of a $3\frac{1}{2}$ in. steam pipe (at the top) having below it a long narrow U shaped portion $\frac{3}{4}$ in. wide and 11 in. high, cast in one with the steam pipe, the water space being between the vertical limbs of the U. The dimensions just given are internal ones, so that the cross-section of the water space is $\frac{3}{4}$ in. by 11 in. by 205 ft. long in each section. The boiler is of cast iron, made in 4 ft. sections flanged at each end; the thickness of the metal being $\frac{3}{8}$ in. It is encased in flat glass $\frac{1}{16}$ in. thick, one sheet 5 in. wide, going over the top of the $3\frac{1}{2}$ in. steam pipe, and two other sheets 15 in. deep being placed, one on each side of the U shaped portion. The glass is supported by small thin channel irons, and encloses an air space around the boiler so as to insulate it against loss of heat by conduction and convection.

The five 205 ft. sections of the Absorber are placed side by

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SHUMAN SUN POWER BOILER.

SCALE _ FULL SIZE.

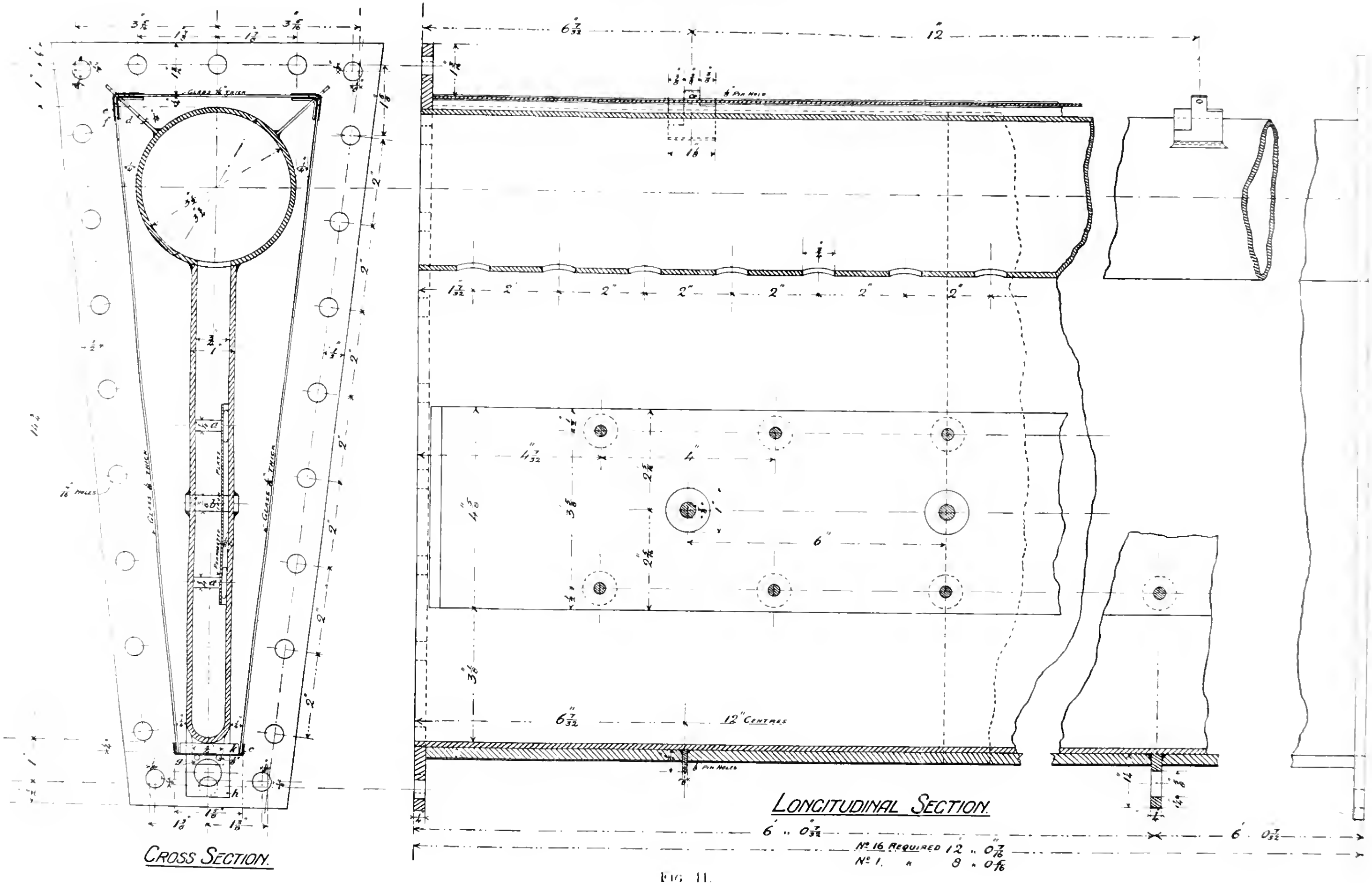
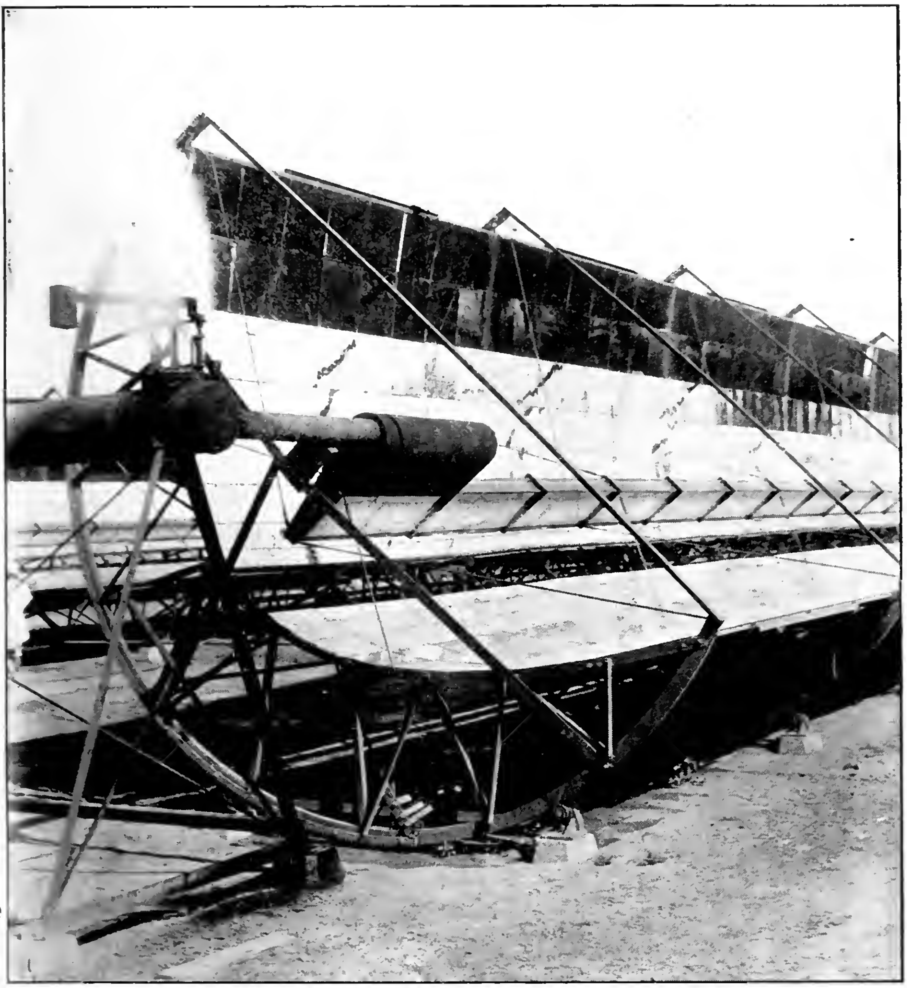


FIG. 11.



G. W. Hilditch. *Photo.*

FIG. 10.

MEADI ABSORBER, 1913. STEAM BLOWING OFF AT $6\frac{1}{2}$ LB. PER SQUARE INCH ABOVE ATMOSPHERIC PRESSURE.

side, and 40 ft. from centre to centre. From the South end of each section a short steam pipe is taken to the steam main which runs East and West. The five short steam pipes are not taken direct from the $3\frac{1}{2}$ in. steam pipe of the boilers, but from the five small steam domes on top of the end sections of the boiler, and the point of connection of each steam pipe to its dome is at the centre of rotation of the mirrors. There is a gland where each short steam pipe enters the steam main, thus allowing for the rotation. A somewhat similar arrangement is made at the northern ends of the boilers where the feedwater enters.

Areas of Land and Sunshine.

Including the space taken by steam and water mains, etc., the total area of land occupied by the whole Absorber measures 218 ft. × 175 ft. = 4239 sq. yds. = 0·875 acre. The overall dimensions of the engine shed, including the projections for the condenser and irrigation pump, are 60 ft. × 26 ft. = 0·036 acre. in addition to the land occupied by the Absorber. Hence the total area necessarily occupied by the plant is 0.911 acre.

From the dimensions given hereinbefore it can be seen that :—

The total area of sunshine collected = 13,752 sq. ft. (Note : of this only 13,269 sq. ft. were available, because 36 ft. run of reflector was not used owing to this length of boiler being missing.)

Total heating surface of boilers = 2,819 sq. ft. (Note : of this only 2,720 sq. ft. were in use for the reason just given.)

$$\text{Gross concentration of sunshine} = \frac{13{,}752}{2{,}819} = 4{\cdot}9.$$

Net ditto (*i.e.*, allowing for loss of sunshine through the gaps 1 ft. 2 in. wide in the mirrors immediately under the boilers) = 4·6.

Water space in boilers per sq. ft. of Sunshine = 7·38 c. ins.

$$\frac{\text{Total area of land occupied by Absorber}}{\text{Total area of sunshine collected}} = \frac{38{,}150 \text{ sq. ft.}}{13{,}752 \text{ sq. ft.}} = 2{\cdot}77$$

Consideration of the Results of the trials of the 1913 Absorber.

In order to show the effect of the changing altitude or zenith distance of the Sun, and to make the results comparable with the Tacony trials, these trials also have been worked out for each hour. Thus, really 35 separate trials have been worked out. To facilitate the study of the results a *Table of Comparison* has been prepared (*vide* p. 107). In looking at this table it will be seen that the area of land occupied by the Meadi Absorber per sq. ft. of radiation collected is 59% more than was occupied by the Tacony Absorber, but as land is cheap where such plants can be used, this is not a matter of much moment.

Judging by the experiments, it appears as if it would be well to increase the water space in the boilers so as to enable the plant to run on during the passage of a cloud across the Sun, and also to enable the mirrors to be rotated from the evening to the morning position by the main engine, which otherwise had to be done by the small petrol engine. Working at about 5 lb. sq. in. above atmosphere was also a great assistance in both of these matters, for the conditions were then much more steady, whereas when

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RESULTS OF TRIALS OF MEADI SUN-POWER PLANT.

No. of trial.	Date and Hour.	Barom. in ins.	Wet bulb thermom °F.	Dry bulb thermom °F.	Diff. °F.	Humidity %	Wind. Speed. Miles per hour	Wind. Direction.	Feed water temp. °F.	Steam press. lb. per sq. in. abs.	Steam temperature °F.	Percentage of moisture in the steam.	Weight of steam produced in lb. per hour.	Rate of absorption of useful heat per sq. ft. of solar radiation in B.T.U. per hour.	Actual evaporation in lb. per hour per sq. ft. of heating surface of boiler.	Thermal Eff. of absorber *	Vacuum in ins. of mercury.	Engine speed r.p.m.	Head over V notch in feet.	Quantity of water pumped in gals. per min.	Total lift, feet.	P.H.P. †	Steam per P.H.P. hour. †	Vacuum pumps driven by.	Condition of Boilers.
1	8th Aug., 1913. 10.15 a.m. to 11.45 a.m.	29.9	76.6	88.4	11.8	58	5.1	NNW	111.6	8.3	184	—	1430	114.0	0.53	% 55.8	25.93	106.9	1.069	1100	26.2	8.7	164	Motor from 10.15 to 10.38 Engine from 10.38 to 11.45	Naked
2	13th Aug., 1913. 11.30 a.m. to 1.0 p.m.	29.9	76.6	93.2	16.6	44	5.6	NNW	115.1	8.3	184	—	1368 (mean 1307)	108.8	0.50	53.3	24.10	89.8	1.134	1289	25.4	9.9	138	Motor	Naked
3	1.0 p.m. to 2.0 p.m.	29.9	76.9	96.0	19.1	39	5.1	NNW	110.0	8.4	185	—	1309	104.5	0.48	51.3	22.86	83.0	0.983	900	25.2	6.9	190	,,	
4	2.0 p.m. to 3.0 p.m.	29.9	76.3	96.9	20.6	36	5.5	NNW	101.9	8.4	185	—	1243	100.1	0.46	48.2	22.54	81.7	0.924	768	25.2	5.8	214	,,	,,
5	3.0 p.m. to 4.0 p.m.	29.8	74.9	96.7	21.8	31	4.5	NNW	99.7	8.4	185	—	1110	89.5	0.41	32.9	20·46	62.6	Not taken	—	—	—	—	,,	.
6	15th Aug., 1913. 2.25 p.m. to 4.05 p.m.	29.9	78	97.0	19.0	40	7.3	N	110.0	15.0	213	5.5	473	38.1	0.17	18.7	25.7	43.4	0.603	266	25.0	2.0	235	Motor	..
7	16th Aug., 1913. 11.10 a.m. to 0.10 p.m.	29.9	77.4	92.6	15.2	49	9.6	NNE	127.6	15.8	216	2·7	648 (mean 645; Total 2,581)	51.4	0.24	25.2	25.86	39.5	0.882	682	25.2	5.2	125	Motor	[illegible]
8	0.10 p.m. to 1.10 p.m.	29.9	77.7	91.8	14.1	51	9.8	NNE	108.5	15.9	216	2·7	652	52.8	0.24	25.9	25.20	38.9	0.849	622	25.2	4.8	136	..	
9	1.10 p.m. to 2.10 p.m.	29.9	79.8	94.6	14.8	50	10.0	NNE	111.3	15.7	216	2·7	698	56.2	0.26	27.6	23.95	37.2	0.819	568	25.2	4.4	159	.	
10	2.10 p.m. to 2.55 p.m.	29.9	79.9	94.3	14.4	50	10.4	NNE	101.3	15·8	216	2.7	583	47.3	0.21	23.2	17.85	28.9	0.599	260	25.0	2.0	292	..	
11	22nd Aug., 1913. 11.10 a.m. to 0.10 p.m.	29.9	73.5	91.7	18.2	40	4.3	NNW	117.0	15.8	216	2.77	1418 (Total 5,584)	113.6	0.52	55.7	25.9	107.9	1.394	2150	26.2	17.1	83	Engine	Covered [illegible]
12	0.10 p.m. to 1.10 p.m.	29.9	74.4	94.0	19.6	37	3.5	NNW	110.9	15.8	216	2.38	1414	114.0	0.52	55.9	26.1	99.1	1.457	2400	26.2	19.1	74	.	
13	1.10 p.m. to 2.10 p.m.	29.9	74.8	95.5	20.7	35	4.9	NNW	111.3	15.8	216	2.77	1442	116.2	0.53	57.0	26.2	100.2	1.441	2340	26.2	18.6	78		,,
14	2.10 p.m. to 3.10 p.m.	29.9	75.5	96.1	20.6	36	4.9	NNW	108.0	15.8	216	2.74	1310	105.8	0.48	51.9	25.7	91.1	1.411	2213	26.2	17.6	74	..	
15	3.10 p.m. to 4.25 p.m.	29.9	74.3	95.8	21.5	33	4.8	NNW	107.3	15.8	216	3.63	1205	97.5	0.44	47.8	25.5	82.1	1.330	1900	26.1	15.1	80	.	
16	25th Aug., 1913. 11.15 a.m. to 0.15 p.m.	30.0	75.3	86.2	10.9	58	7.3	NE	99.0	15.7	215	—	1031 (mean 1,046; Total 4,184)	83.9	0.38	41.2	27.0	102.6	1.286	1760	25.3	13.5 (mean 13.1)	76	Engine	
17	0.15 p.m. to 1.15 p.m.	30.0	75.6	86.8	11.2	58	7.3		102.8	15.7	215	3.87	1132	91.8	0.42	45.0	26.9	109.1	1.316	1850	25.4	14.2	80		
18	1.15 p.m. to 2.15 p.m.	30.0	76.2	88.1	11.9	56	7.2	NNW	102.8	15.7	215	3.34	1068	86.7	0.39	42.5	26.6	103.3	1.279	1732	25.3	13.3	80		
19	2.15 p.m. to 3.15 p.m.	30.0	76.7	88.2	11.5	58	7.0		94.8	15.8	216	3.81	953	78.0	0.36	38.2	26.2	85.3	1.198	1470	25.3	11.3	85		

	16th Aug., 1913.																								
7	11.10 a.m. to 0.10 p.m.	29.9	77.4	92.6	15.2	49	9.6	NNE	127.6	15.8	216	2·7 mean 645	648	Total 2,581 51.4	0.24	25.2	25.86	39.5	0.882	682	25.2	5.2	125	Motor	[illegible]
8	0.10 p.m. to 1.10 p.m.	29.9	77.7	91.8	14.1	51	9.8	NNE	108.5	15.9	216	2·7	652	52.8	0.24	25.9	25.20	38.9	0.849	622	25.2	4.8	136	..	
9	1.10 p.m. to 2.10 p.m.	29.9	79.8	91.6	14.8	50	10.0	NNE	111.3	15.7	216	2·7	698	56.2	0.26	27.6	23.95	37.2	0.819	568	25.2	4.4	159	..	
10	2.10 p.m. to 2.55 p.m.	29.9	79.9	94.3	14.4	50	10.4	NNE	101.3	15·8	216	2.7	583	47.3	0.21	23.2	17.85	28.9	0.599	260	25.0	2.0	292	..	
	22nd Aug., 1913.																								
11	11.10 a.m. to 0.10 p.m.	29.9	73.5	91.7	18.2	40	4.3	NNW	117.0	15.8	216	2.77	1418 Total 5,584	113.6	0.52	55.7	25.9	107.9	1.394	2150	26.2	17.1	83	Engine	Covered and freshly painted [illegible]. Mirrors quite clear.
12	0.10 p.m. to 1.10 p.m.	29.9	74.4	94.0	19.6	37	3.5	NNW	110.9	15.8	216	2.38	1414	114.0	0.52	55.9	26.1	99.1	1.457	2400	26.2	19.1	74	..	
13	1.10 p.m. to 2.10 p.m.	29.9	74.8	95.5	20.7	35	4.9	NNW	111.3	15.8	216	2.77	1442	116.2	0.53	57.0	26.2	100.2	1.441	2340	26.2	18.6	78		..
14	2.10 p.m. to 3.10 p.m.	29.9	75.5	96.1	20.6	36	4.9	NNW	108.0	15.8	216	2.74	1310	105.8	0.48	51.9	25.7	91.1	1.411	2213	26.2	17.6	74	..	.
15	3.10 p.m. to 4.25 p.m.	29.9	74.3	95.8	21.5	33	4.8	NNW	107.3	15.8	216	3.63	1205	97.5	0.44	47.8	25.5	82.1	1.330	1900	26.1	15.1	80	..	..
	25th Aug., 1913.																								
16	11.15 a.m. to 0.15 p.m.	30.0	75.3	86.2	10.9	58	7.3	NE	99.0	15.7	215	— mean 1,046	1031	Total 4,184 83.9	0.38	41.2	27.0	102.6	1.286	1760	25.3	mean 13.1 13.5	76	Engine	
17	0.15 p.m. to 1.15 p.m.	30.0	75.6	86.8	11.2	58	7.3		102.8	15.7	215	3.87	1132	91.8	0.42	45.0	26.9	109.1	1.316	1850	25.4	14.2	80	..	
18	1.15 p.m. to 2.15 p.m.	30.0	76.2	88.1	11.9	56	7.2	NNW	102.8	15.7	215	3.34	1068	86.7	0.39	42.5	26.6	103.3	1.279	1732	25.3	13.3	80	.	
19	2.15 p.m. to 3.15 p.m.	30.0	76.7	88.2	11.5	58	7.0		94.8	15.8	216	3.81	953	78.0	0.36	38.2	26.2	85.3	1.198	1470	25.3	11.3	85	..	
20	3.15 p.m. to 4.15 p.m.	30.0	76.9	87.8	10.9	59	6.6	NE	108.3	15.7	215	3.46	886	71.5	0.34	35.0	26.0	80.8	1.174	1440	25.3	10.7	83	..	
	27th Aug., 1913.																								
21	10.15 a.m. to 11.15 a.m.	29.9	76.6	86.5	9.9	63	5.5	N	98.3	15.8	216	3.20	1080	88.0	0.40	43.2	27.2	99.8	1.332	1920	24.8	14.4	75	Engine	
22	11.15 a.m. to 0.15 p.m.	29.9	76.3	87.0	10.7	60	6.2		108.2	15.7	215	3.40	1084	87.5	0.40	42.8	27.4	100.9	1.380	2090	24.9	15.8	69	..	
23	0.55 p.m. to 1.55 p.m.	29.9	76.3	87.5	11.2	59	5.7	N	104.3	19.2	225	4.65	1122	91.2	0.41	44.7	27.6	101.6	1.311	1842	24.6	13.8	81		
24	1.55 p.m. to 2.55 p.m.	29.9	76.0	87.6	11.6	57	6.1		103.9	19.2	225	5.02	1104	89.8	0.41	44.0	27.5	90·3	1.291	1775	24.6	13.3	83		
25	2.55 p.m. to 3.55 p.m.	29.9	76.0	87.8	11.8	57	6.5	N	99.8	19.1	225	5.08	970	79.2	0.36	38.8	27.5	83.5	1.230	1570	24.6	11.7	83		
26	3.55 p.m. to 4.25 p.m.	29.9	76.0	87.0	11.0	58	5.8	—	98.0	19.1	225	4.95	750	61.4	0.28	30.1	27.2	66.2	1.134	1288	24.5	9.6	78	.	
	28th Aug., 1913.																								
27	11.10 a.m. to 0.10 p.m.	29.9	77.3	87.4	10.1	63	3.9	NW	111.8	8.7	187	— mean 1,311	1222	Total 5,362 97.4	0.45	47.5	26.5	78.1	1.259	1670	24.4	mean 13.2 θ 12.4	99	Chiefly the Engine	
28	0.10 p.m. to 1.10 p.m.	29.9	77.2	87.5	10.3	62	5.1	NW	110.9	8.3	184	19.0	1346	107.0	0.50	52.5	25.8	82.4	1.350	1980	24.5	14.7	92		
29	1.10 p.m. to 2.10 p.m.	29.9	77.4	88.5	11.1	59	5.0	—	113.2	8.6	186	15.3	1434	114.0	0.53	55.8	25.4	79.5	1.302	1814	24.5	13.4	107		.
30	2.10 p.m. to 3.10 p.m.	29.9	77.3	89.0	11.7	58	6.4	NW	115.8	8.4	185	12.4	1360	108.0	0.50	52.9	25.0	80.5	1.290	1775	24.5	13.2	103		.
	29th Aug., 1913.																								
31	10.15 a.m. to 11.15 a.m.	29.9	77.7	87.7	10.0	63	3.4	NE	115.8	8.3	184	3.7	1347	107.0	0.50	52.5	26.1	97.0	1.332	1920	24.2	14.1*	96	Engine	Mirrors slightly [illegible]
32	11.15 a.m. to 0.15 p.m.	29.9	77.9	89.3	11.4	58	4.7	NE	116.2	8.3	184	7.7	1336	106.2	0.49	52.1	26.2	98.2	1.319	1870	24.2	13.7	98	..	
	30th Aug., 1913.																								
33	0.10 p.m. to 1.10 p.m.	29.9	78.3	91.9	13.6	52	6.5	—	113.0	22.8	235	—	190	81.2	0.34	39.8	14.5	—	—	—	—	—	—	Motor because main engine not running	Mirrors [illegible]
34	1.10 p.m. to 2.10 p.m.	29.9	78.6	91.9	13.3	53	6.4	N	113.2	22·9	235	—	217	‡ 92.8	0.39	45.5	12.7	—	—	—	—	—	—		
35	2.10 p.m. to 3.10 p.m.	29.9	78.9	91.8	12.9	54	6.8	—	108.6	22.9	235	—	184	72.2	0.33	35.4	12.1	—	—	—	—	—	—		

* Based on 2.05 calories per sq. cm. per min. as the value of the solar constant, and a mean coefficient of atmospheric transmission of 45%. For explanation and later values *vide* p. 118.

† The low values of the figures in this column are due to the poor condition of the engine-end of the plant, and have nothing to do with the utilization of solar energy *per se*. For a detailed explanation see p. 144.

θ The better vacuum on the 28th compared with that on the 13th accounts for these very different results with near the same pressure and quantity of steam.

‡ Only one of the five boilers in use.

TABLE OF COMPARISON.

		Model 1910	Tacony 1911	Meadi 1913
1.	Total area of solar radiation collected	15 sq. ft.	10,296 sq. ft.	13,752 sq. ft.
2.	Total heating surface of boilers	15 sq. ft.	5,005 sq. ft.	2,819 sq. ft.
3.	Total area of land occupied by Absorber	—	0.41 acre	0.88 acre
4.	Total area occupied by Absorber divided by the total area of radiation collected	—	1.74	2.77
5.	Cubic inches of water in boiler per sq. ft. of sunshine collected	—	7.14	7.38
6.	Sq. ft. of radiation concentrated on one sq. ft. of boiler surface	1.0	2.0	4.6
7.	Evaporation per hour from and at 212°F. per sq. ft. of heating surface (All calculated from the best run of one hour at atmospheric pressure)	0.075 lb.	0.184 lb.	0.587 lb.
8.	Evaporation per hour from and at 212°F. per sq. ft. sunshine collected (All calculated from the best run of one hour at atmospheric pressure)	0.075 lb.	0.090 lb.	0.120 lb.
9.	Evaporation per hour from and at 212°F. per ft. run of Absorber (All calculated from the best run of one hour at atmospheric pressure)	0.225 lb.	0.543 lb.	1.614 lb.
10.	Rate of Absorption of heat in B.T.U. per hour,			
	(*a*) per sq. ft. of radiation collected (All calculated from the best run of one hour at atmospheric pressure)	72 B.T.U.	88 B.T.U.	116 B.T.U.
	(*b*) per sq. ft. of heating surface (All calculated from the best run of one hour at atmospheric pressure)	72 ,,	181 ,,	570 ,,
11.	Maximum quantity of heat that could be absorbed by a perfect sun heat Absorber in B.T.U. per sq. ft. per hour	299 ,,	299 ,,	299 ,,
12.	Thermal efficiency of Absorber for the best run of one hour at atmospheric pressure	24.1%	29.5%	40.7%
13.	Total area of land occupied by Absorber divided by maximum Pump Horse Power	—	—	222 sq. yds.*
14.	Area of radiation collected per Pump Horse Power...	—	—	695 sq. ft.*
15.	Length of absorber per Pump Horse Power	—	—	54 ft.*

* The low values of these figures are due to the bad condition of the engine and pumps. For a detailed explanation see p. 144.

working at 8 lb. sq. in. abs. everything seemed to be in unstable equilibrium, and the regulation of the speed of the engine was far more difficult. Owing to the large water-surface of the boilers, the number of attached bubbles of steam was very great, and a small reduction in the steam pressure caused these to expand and upset the water-level in the boilers.

Evaporation per sq. ft. of heating surface.

The evaporation per sq. ft. of heating surface shows a great increase over that of the 1911 design. This is not a comparative result owing to the boilers being of such different types, so the figure is of little value, but the one really *splendid* result, on which a strict comparison of the three types of Absorber can be made, is the steam produced per sq. ft. of solar radiation per hour. (Item No. 8 of the table on p. 107.) Starting with 0.075 lb. for the 1910 model, the Tacony Absorber gave 0.090 lb., *i.e.*, 20% more, and the Meadi Absorber gave 0·120 lb., *i.e.*, 33⅓% more than the Tacony one, and 60% more than the model. This it will readily be admitted is a great achievement. This 33⅓% increase was due to Prof. Boys' modification of the Shuman Absorber, and to the better thermal value of the Egyptian sunshine compared with the Tacony sunshine. We leave it to Prof. Boys to fight it out with the Sun as to what is his exact share of the 33⅓% ! Immediately depending on the figures just considered are the rates of absorption per sq. ft. of radiation (Item No. 10) and the thermal efficiencies of the three types (Item No. 12). These it will be seen have increased from 24·1% to 29·5% and then to 40·7% (calculated on the basis of a max. transmission of 70% and a solar constant of 1·93)—results to be proud of.

Coming to the tabulated results of the trials much could be written on them, but the following are the important features :—

Effect of Humidity.

Considering the trials made on 22nd and 25th August, 1913, the steam pressure and the condition of the Absorber were the same, and the time of day corresponded almost exactly, but while the humidity averaged only 36·2% on 22nd, it was 57·8% on 25th. The total weight of steam produced on 22nd was 6,789 lb., and on 25th only 5,170 lb. That is 31·3% more steam was produced on 22nd than on 25th. This result may be somewhat masked by the effect of the wind, the speed of which was only about 5 miles per hour on 22nd August, while it was about 7 miles per hour on 25th, and wind almost certainly decreases the steam production. It is also to be noticed that on the 8th August (naked boilers*) the steam production (1,430 lb.) was greater when the humidity was 58% than it was (1,368 lb.) on the 13th August when the

* By "naked boilers" is meant that the clear glass covers had been removed, thus the boilers were then not lagged with hot-air.

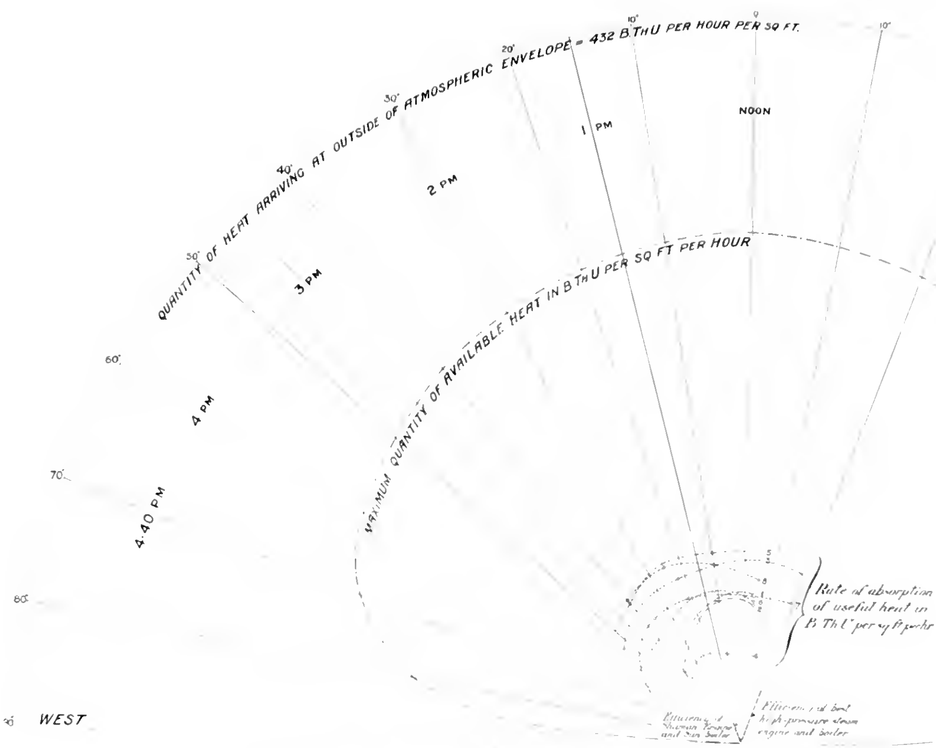

FIG. 17.

POLAR CURVES [illegible]

The radii vectors are the rate of absorption in B.Th.U. per sq. ft. per hour.

Reference No.	Place	Date	Condition of boiler	Mean steam pressure lb. per sq. in. abs.	Mean humidity per cent.
1	Lacony	10.8.11		13.0	41.6
2	..	12.8.11		11.7	51.8
3	Meadi	13.8.13	Naked boiler	8.4	37.5
4	..	16.8.13	Naked boiler and dusty mirrors	15.8	50.0
5	..	22.8.13	Covered and freshly painted black. Mirrors clean	15.8	36.2
6		26.8.13	.. ..	15.7	57.8
7	..	27.8.13	.. ..	15.8 / 19.2	59.0
8	..	28.8.13	.. ..	8.5	60.5

humidity was only 44%, the steam pressures, being of course the same in both cases, and the wind speed being nearly so, though the time of day did not quite correspond. If the periods had corresponded the results of the 8th would probably have been still greater.

Effect of Steam pressure on Steam production.

With regard to the effect of the steam pressure on the steam production, a most remarkable difference is shown between the results of 13th and 16th August, the steam production at 8 lb. per sq. in. abs., being about twice what it was at 16 lb. per sq. in. abs., the boilers being naked on both occasions. The speed of the wind on the 16th was about double what it was on the 13th, and this no doubt partly accounts for the smaller quantities of steam on the 16th. The pump horse power was also considerably greater with the lower pressure. On studying the effect of steam pressure on the steam production and the power, when the boilers are covered with glass, we see that the effect is not nearly so marked; *e.g.*, the humidity was about the same on the 25th (excluding all the results for the last hour) and 28th August. The steam pressure was about 16 lb. per sq. in. abs. on the former date and 8 lb. per sq. in. abs. on the latter, but the steam produced was only 28·2% more, and the mean pump horse power was the same at the lower pressure. If we compare the results of 22nd August with those of 28th, then more steam and power were produced at the higher pressure, but the humidity was so very much less on the 22nd that it prevents a proper comparison, and was probably the cause of the best results having been obtained on that day.

Comparison of naked and covered boilers.

With regard to naked and covered boilers, the steam production on 22nd August, when the boilers were covered, was over double what it was on 16th August when they were naked, but the humidity and the speed of the wind were much lower on 22nd than on 16th, so the results are not exactly comparable. The results of the 25th (excluding the last hour) may be compared with those of the 16th and they show 62% more steam in favour of the covered boilers. Almost in contradiction of this comparison at 16 lb. per sq. in. abs., it will be noticed when comparing the results of 13th August with those of 28th August (both at 8 lb. per sq. in. abs.) that the mean steam production per hour was only slightly greater with the covered boilers, though this may be partly accounted for by the much higher humidity on 28th August.

However, different quantities of steam at different pressures are not directly comparable, but we may compare them by considering them as being supplied to a perfect engine working on the Carnot cycle. The comparative values, which may be

No. of trial.	Humidity. %	Steam pressure in lb. sq. in. abs.	Condition of boiler.	Value figure.	Time of day.
1	58	8 .25	Naked	170 .8	10.15—11.45
2	44 mean 39·7 mean 37·5	8 .25	,,	163 .4 mean 156·1	11.30—1.0
3	39	8 .4	,,	156 .4	1.0—2.0
4	36	8 .4	,,	148 .4	2.0—3.0
5	31	8 .4	,,	132 .6	3.0—4.0
6	40	15 .0	,,	73 .7	2.25—4.05
7	49 mean 50	15 .8	Naked and dusty	103 .7 mean 103·3	11.10—0.10
8	51	15 .9	,,	104 .4	0.10—1.10
9	50	15 .7	,,	111 .8	1.10—2.10
10	50	15 .8	,,	93 .2	2.10—2.55
11	40 mean 36·2 mean 37	15 .8	Covered and black.	227 .0 mean 217.2	11.10—0.10
12	37	15 .8	,,	226 .0	0.10—1.10
13	35	15 .8	,,	231 .0	1.10—2.10
14	36	15 .8	,,	209 .4	2.10—3.10
15	33	15 .8	,,	192 .8	3.10—4.25
16	58 mesn 57·8 mean 57·5	15 .7	Covered and black.	165 .0 mean 167·4	11.15—0.15
17	58	15 .7	,,	181 .0 mean 168·2	0.15—1.15
18	56	15 .7	,,	171 .0	1.15—2.15
19	58	15 .8	,,	152 .5	2.15—3.15
20	59	15 .7	,,	141 .8	3.15—4.15
21	63	15 .8	,,	172 .8	10.15—11.15
22	60	15 .7	,,	173 .5	11.15—0.15
23	59	19 .2	,,	192 .8	0.55—1.55
24	57	19 .2	,,	189 .8	1.55—2.55
25	57	19 .1	,,	167 .0	2.55—3.55
26	58	19 .1	,,	129 .0	3.55—4.25
27	63 mean 60·5	8 .7	,,	147 .9 mean 160·5	11.10—0.10
28	62	8 .3	,,	157 .4	0.10—1.10
29	59	8 .6	,,	173 .5	1.10—2.10
30	58	8 .4	,,	163 .2	2.10—3.10
31	63	8 .3	Covered and black and mirrors slightly dusty	157 .4	10.15—11.15
32	58	8 .3	,,	156 .2	11.15—0.15
33	52	22 .8	Covered and black and mirrors dusty	173 .9 mean 180·2	0.10—1.10
34	53	22 .9	,,	198 .5	1.10—2.10
35	54	22 .9	,,	168 .3	2.10—3.10

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POLAR CURVES SHOWING RESULTS OBTAINED WITH SUN HEAT ABSORBERS AT TACONY AND MEADI.

The radii vectores are the heat values of the total quantity of steam produced per hour

The letters a-k refer to the Tacony trials, and the numbers are those of the Meadi trials

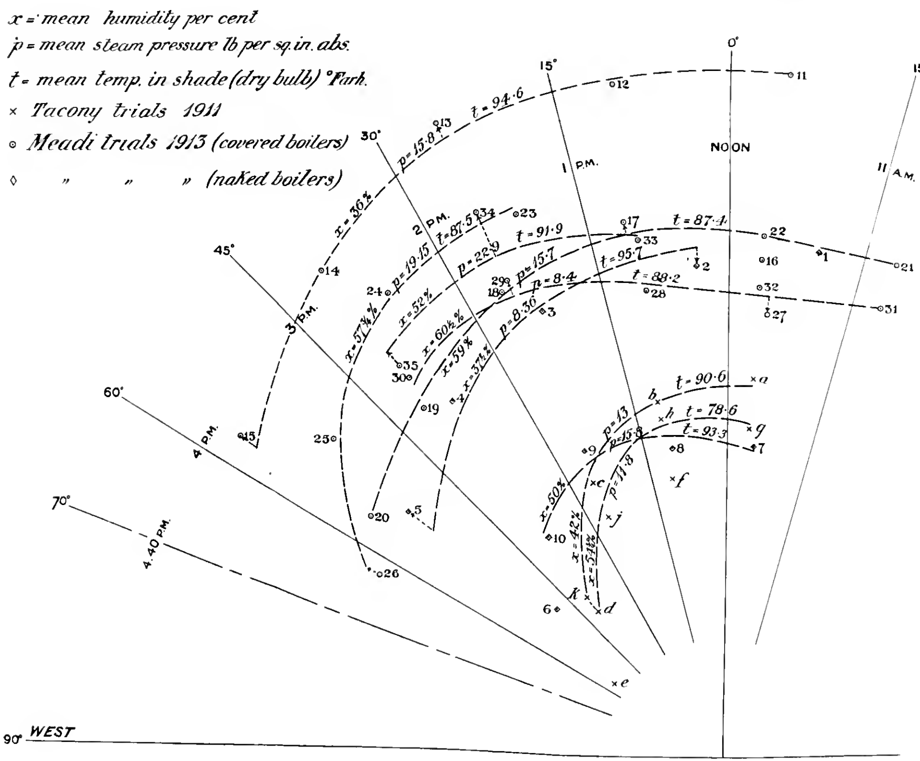

FIG 12A.

NOTE WITH REFERENCE TO FIGS. 12 AND 12A.

On comparing the rates of absorption given in the table facing p. 106 with the corresponding value-figures on p. 110 it will be seen that the rate of absorption is not a measure of the value of the steam for power purposes. The polar curves of Fig. 12, though correct in themselves, are therefore somewhat misleading as regards steam values, because the rates of absorption have been plotted as radii vectores. Hence another set of polar curves has been plotted with the heat-values (for power purposes, *Vide* p. 113) of the total quantities of steam produced per hour as radii vectores, and it will be found that the positions of the corresponding curves on Figs 12 and 12A are very different. Fig. 12A gives us the information we require for practical use, and enables us to arrive at some of the conclusions given on p. 114.

Hence it will be seen that a high thermal efficiency of the boiler is not necessarily accompanied by a high value of the steam for power purposes. The reason for this is that when the steam pressure is low (8·4 lb. sq. ins. abs., Curve No. 3, Fig. 12) the temperature of the inside of the boiler is low. Therefore the difference of temperature between the inside and the outside of the boiler is great, and consequently the rate of transmission of heat into the boiler is high. This means a high thermal efficiency, but the value of the low-pressure steam for power purposes is low (last par. p. 109 and value figures on p. 110), while, on the other hand, when the steam pressure is high (19·15 lb. sq. in. abs. Curve for trials No. 23–26 inclusive on Fig. 12A) the temperature difference between the inside and outside of the boiler is less, and the thermal efficiency is less, but the value of the high-pressure steam is high, and that is what is required commercially.

called the "value figures," will thus vary as $W \frac{T_1 - T_2}{T_1}$, where W is the weight in lb. of steam produced per hour, and T_1 and T_2 are the absolute temperatures in °F. of the steam and the condenser respectively. T_2 has been taken as constant and equal to 568°F. which corresponds with a vacuum of $27\frac{1}{2}$ in. of mercury. The value figures are tabulated on p. 110, and to facilitate the study of the results by their aid, the necessary data have been reproduced from the large table. The curves in Fig. 13 have been plotted with the value figures as ordinates and the percentage humidity as abscissae.

Equation to the Steam Curves. Nobody can regret more than the author that there are not more experimental results upon which to base generalizations, but we must do the best we can with the data available and correct our conclusions should they need it when further experiments have been made.

By inspection of the curves in Fig. 13 for a steam pressure of 15·8 lb. per sq. in. abs. we see that the equation to the curves is of the form

$$y = b - c_1 \ x$$

where $b \propto E_0 \ a^{\text{sec. z.}}$; x = the humidity per cent, and $c_1 = \tan\theta$

$$\therefore y = k \ E_0 \ a^{\text{sec. z.}} - x \tan\theta \quad .. \quad .. \quad .. \quad (1)$$

k being a constant.

The curve 14—19 appears to have the mean slope: from it we find $\tan\theta = 2 \cdot 58$.

Now the line 14—19 is for trials lasting from $2.12\frac{1}{2}$ o'clock to $3.12\frac{1}{2}$ o'clock. Hence the mean zenith distance of the Sun during these trials was $40\frac{1}{2}$°;

$$\text{and } E_0 \ a^{\text{sec. } 40\frac{1}{2}°} = 1 \cdot 93 \times 0 \cdot 627 = 1 \cdot 211$$

$$\therefore \quad y = k \ 1 \cdot 211 - 2 \cdot 58 \ x.$$

Putting in corresponding values of x and y read off from the curve 14—19 we find that the value of the const. $k = 247$

$$\therefore \quad y = 302 - 2 \cdot 58 x \quad .. \quad .. \quad (2)$$

Putting in the limits we see that

when $y = 0$, $x = 117$

and when $x = 0$, $y = 302$

The 117° humidity implies super-saturation, but it may also indicate that the equation is not correct for such extreme cases as the limits.

Proceeding in exactly the same manner, but using the curve 13—18, we find

$z = 25\frac{1}{2}°$; $E_o\, a^{\text{sec. } z.} = 1 \cdot 332$; $k = 246 \cdot 5$

and $\therefore$ $y = 330 - 2 \cdot 83\, x$.

Putting in the limits

when $y = 0$, $x = 116 \cdot 7$

when $x = 0$, $y = 330$

The agreement of the limiting value of x with that previously obtained is to be noted.

Taking $k = 247$ and $E_o = 1 \cdot 93$ ($\therefore kE_o = 477$) the equation has been worked out for the following conditions, *i.e.*, for points which are not on any of the plotted curves :—

Time.	Z.	x %	Value-figure from equation.	Value-figure from diagram.	Percentage error of the equation.
0 .40 p.m.	10°W	45	220	208	+5 .5%
3.20 p.m.	50°W	45	162	176	—8 .6%
0.40 p.m.	10°	32	253 .5	241	+4 .8%
3.20 p.m.	50°	32	195 .5	205	—4 .6%

With regard to the errors, it must be remembered that Bouguer's equation does not hold well for large zenith distances, and as the author's equation embodies Bouguer's, it also does not hold very well for angles exceeding 55° or 60°.

Effect of Pressure included in the Equation.

We may introduce a term into equation (1) so as to take into account the effect of the steam pressure. Consider the curves for trials made between 1.12½ o'clock and 2.12½ o'clock for steam pressures of 15·8 and 22·9 to 19·0 lb. sq. in. abs. We find that the ratio of the value figures for $p = 15 \cdot 8$ and $= 22$, is $\dfrac{196 \cdot 5}{174 \cdot} = 1 \cdot 13$; that the corresponding ratio when $p = 8 \cdot 5$ and $= 15 \cdot 8$, is $\dfrac{171}{151} = 1 \cdot 13$; and that the difference of the pressures causing the difference in the value figures is $22 - 15 \cdot 8 = 6 \cdot 2$ in one case, and $15 \cdot 8 - 8 \cdot 3 = 7 \cdot 5$ in the other, or a mean diff. of 6·8 lb. sq. in. abs.

Hence we are led to the term—

$1 \cdot 13^{\frac{p - 15 \cdot 8}{6 \cdot 8}}$ (where p = the steam press. in lb. sq. in. abs. as that for making the equation apply approximately to different

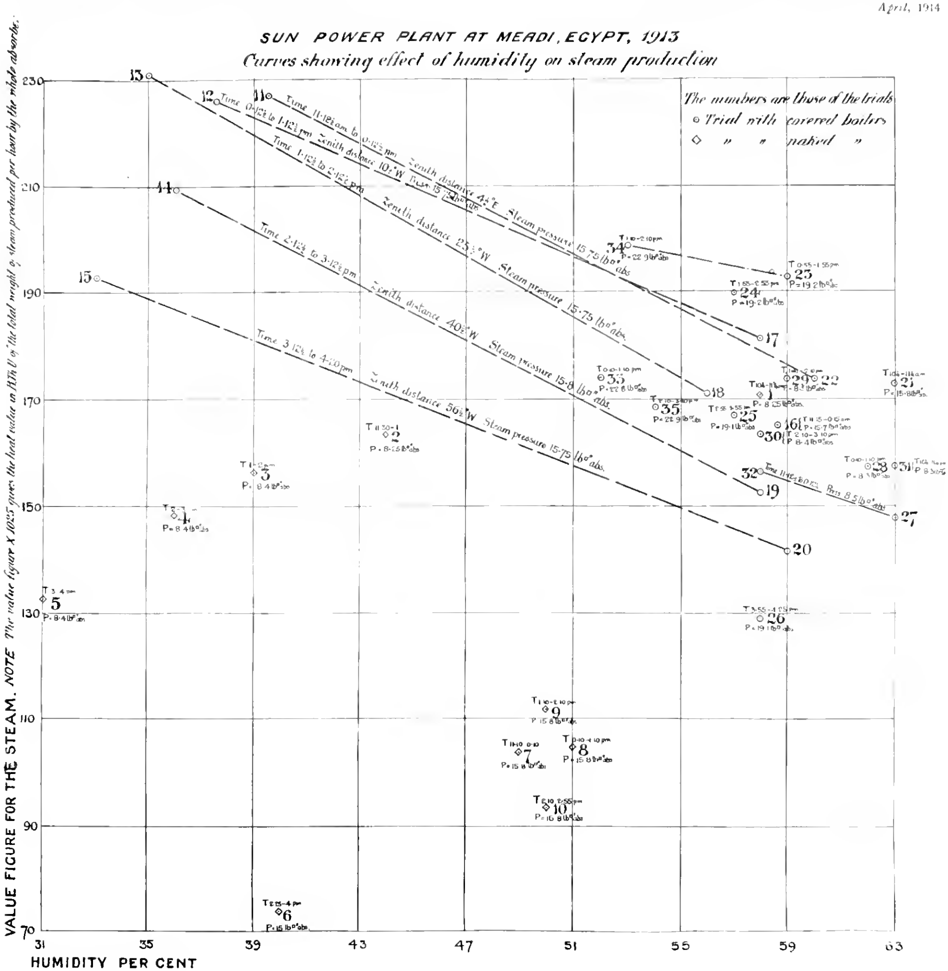
SUN POWER PLANT AT MEADI, EGYPT, 1913
Curves showing effect of humidity on steam production
The numbers are those of the trials
Trial with covered boilers
" " naked "
VALUE FIGURE FOR THE STEAM. NOTE The value figure x 1025 gives the heat value in B.Th.U. of the total weight of steam produced per hour by the whole absorber.
HUMIDITY PER CENT
Time 11-12½ am to 0-12½ pm Zenith distance 4½° E Steam pressure 15.75 lbs° abs
Time 1-12½ to 2-12½ pm Zenith distance 25½° W Steam pressure 15.75 lbs° abs.
Time 2-12½ to 3-12½ pm Zenith distance 40½° W Steam pressure 15.8 lbs° abs.
Time 3-12½ to 4-10 pm Zenith distance 56½° W Steam pressure 15.75 lbs° abs.
Time 11.10 to 0.10 Press 8.5 lbs° abs

Fig. 13.

steam pressures, but it must be remembered we have extremely little information on which to base this term, and it is to be taken merely as an indication of the probable procedure when more data are available.

Hence equation (1) becomes :—

$$y = 1\cdot 13^{\frac{p-15\cdot 8}{6\cdot 8}} \left(k\,E_0\,a^{\sec. z.} - x \tan \theta\right) \quad .. \quad .. \quad (3)$$

It has been explained that to save labour the " value figures " have been taken as $= W \frac{T_1 - T_2}{T_1}$ for a particular percentage of humidity. Now if once and for all we find the relation between the " value figure " and the product of W into the corresponding thermal value of a pound weight of steam used between the same limits of temperature, we shall be able to introduce a constant factor c into the equation so that the latter will give the absolute value in B.T.U. of the total weight of steam produced per hour by the whole Absorber on the supposition that the steam is used in an engine working on the Rankine cycle, *i.e.*, $c = \frac{WS}{\text{val. fig.}}$ S having the meaning indicated in equation (4). When so working between the limits of T_1, and T_2 the value of steam is—

$$S \text{ (in B.T.U. per lb.)} = (T_1 - T_2)\left(1 + \frac{L_1}{T_1}\right) - T_2 \log_\epsilon \frac{T_1}{T_2} \quad .. \quad (4$$

where L_1 is the latent heat of the steam per lb. at T_1.

For $p = 15\cdot 8$ lb. sq. in. abs., $T_1 = 676°$F., and T_2 is taken as = 568°F. as before.

Hence S = 164 B.T.U. per lb.

The product WS and the value figure must correspond as regards humidity. Reading from the curve 14—19, and taking $x = 36\%$ we find the value figure = 210, and W = 1310 lb. per hour, hence—

$$c = \frac{WS}{\text{val. fig.}} = \frac{1310 \times 164}{210} = 1023$$

Doing this for two other sets of values we find $c = 1026$ and $c = 1025$. We take the latter as the mean value.

Thus, if we multiply the value figures by 1025 the product is the total heat value of the steam produced by the whole Absorber in B.T.U. per hour.

Hence the following equation (5) takes into account :—

(*a*) the time of day, or zenith distance ($=z$).

(*b*) the humidity at that time ($=x$).

(*c*) the steam pressure in lb. per sq. in. abs. ($=p$.)

and on the values of these quantities being inserted, the equation gives the heat value in B.T.U. of the total weight of steam produced by the whole Absorber per hour.

$$y = 1{,}025 \times (1\cdot 13)^{\frac{p-15\cdot 8}{6\cdot 8}} (477 \times 0\cdot 70^{\text{sec. }z.} - 2\cdot 58x) \quad .. \quad (5)$$

[Note.—Values of $0\cdot 70^{\text{sec. }z.}$ for a number of angles will be found on p. 118.]

The conclusions which we are able to arrive at on studying the above results and the curves are :—

(1) That when the boilers are naked it is better to work at a pressure of 8 lb. per sq. in. abs. than at 16 lb. per sq. in. (*Cf.* trials 2 to 4 with trials 7 to 10.)

(2) That when working at 8 lb per sq. in. abs. a rise of 20·8% in the mean humidity, *i.e.*, from a mean of 39·7% to a mean of 60.5% causes nearly as much decrease in the steam production as covering the boilers causes an increase. (*Cf.* trials 27 to 30 with trials 2 to 4.)

If the cost of covering the boilers be taken into account the balance would be in favour of the naked boilers, provided the percentage humidity and the speed of the wind were always small.

(3) That when working at a pressure of 16 lb. sq. in. with covered boilers, the effect of humidity is unmistakable. *E.g.*, a rise of 21·6% in the mean humidity (from a mean of 36·2% to a mean of 57.8%) caused a decrease of 55 in the value figure. (*Cf.* trials 11 to 15 with trials 16 to 20.)

(4) That it is better to work at a pressure of 16 lb. sq. in. abs. than at 8 lb. sq. in. abs. when the boilers are covered. (*Cf.* trials 16 to 19 with trials 27 to 30.)

(5) That it is better to work at a steam pressure of 19 lb. sq. in. abs. than at 16 lb. sq. in. abs. when the boilers are covered. This is clearly shown when trials 23 to 25 are compared with trials 18 to 20, the humidity being practically the same in both sets.

(6) That the advantage of higher pressures just pointed out does not appear to hold when a pressure of 23 lb. sq. in. abs. is compared with one of 19, especially when the fact is taken into account that the percentage humidity was higher when the pressure was lower, though the dust on the mirrors may have vitiated the comparison. (*Cf.* trials 34 and 35 with trials 23 and 24). This seems to imply that, for this particular design of Absorber a pressure of 23 lb. per sq. in. abs. is too high to be economical.

(7) That when working at a pressure of 16 lb. sq. in. abs. the good effect of covering the boilers is most marked, as will be seen by comparing trials 16 to 19 with trials 7 to 10, and this in spite of the fact that when the boilers were covered the mean humidity was greater (57·5%) than when they were naked (mean humidity 50%).

(8) That for a given area of boiler surface and concentration of solar radiation, there is probably a certain maximum steam

pressure which would give a maximum economy. If that pressure were increased the loss of heat by radiation from the boiler would more than compensate for the greater heat value of the steam per lb., but if the concentration of the solar radiation were increased, then for a given boiler surface the maximum steam pressure could probably be increased.

Moisture in steam.

The author is not able to account for the discordant percentage of moisture in the steam on 28th August. The results certainly seem wrong that day when compared with all the others.

Constancy of steam production.

It was very satisfactory to find that the production of steam throughout the day was much more nearly constant than might be expected, and far more so than was the case with the 1911 Tacony Absorber, the units of which were placed with their major axes East and West, whereas the Meadi ones are placed North and South. Considering the five trials made on August 25th, 1913, and taking the mean of 1,031 lb., and 1,132 lb (= 1,081 lb.) as the mid-day hour quantity of steam, we see that there was an increase during the first hour after mid-day of (1,132 – 1,081 =) 51 lb., or 4·7% on 1,081 lb. During the second hour there was a decrease of (1,081 – 1,068 =) 13 lb., or 1·2% on 1,081 lb. During the third hour the decrease was (1,068 – 953 =) 115 lb., or 10·6% on 1,081 lb. and during the fourth hour (953 – 886 =) 67 lb., or 6·2% on 1,081 lb.

This satisfactory result is due to the rotation of the mirrors, which causes the number of rays collected in the morning and evening to be the same as at mid-day, and renders the plant much more useful for power purposes other than irrigation, but it must be remembered that it was not found possible to make a full time test from early morn to late afternoon, so that the complete curve of steam production is not known.

Maximum Pump Horse Power Developed.

The maximum pump horse-power was obtained between noon and 1.0 p.m. on 22nd August, 1913, when it averaged 19 for the hour. The only other day on which such a result was even approached was between 11.15 a.m. and 0.15 p.m. on 27th August when the P.H.P. was 15·8. These results are are, of course, exceedingly bad and are largely, if not entirely, due to the condition of the engine end of the plant, details of which will be found on p. 144. In themeant ime it suffices to say that the slip of the irrigation pump was about 25%, that the steam valves of the engine leaked badly, and that the vacuum was a low one. In consequence of these poor results, the steam consumption per P.H.P. hour was exceedingly high, the best result being 74 lb. of steam per hour, which was obtained twice on 22nd August. To have been at all a good result for this type of plant the consump-

tion should certainly not have exceeded 30 lb. of steam per P.H.P. hour.

The maximum steam production for any hour was 1,442 lb., obtained between 1.10 and 2.10 p.m. on 22nd August. The author's tests of the Shuman Low Pressure engine at Erith gave an economy of 22·1 lb. steam (at 16·2 lb. sq. in. abs.) per B.H.P. hour when the total B.H.P. was 94½. With an output of about 60 B.H.P. the consumption would be about 26 lb. per B.H.P. hour, and dividing the 1,442 by 26 we have the interesting fact that had the Erith engine been connected to the Meadi Absorber the maximum output would have been 55·5 B.H.P. With the Erith engine and a good irrigation pump, the P.H.P. for the same hour would have been about 50.

A fairer way of considering how much B.H.P. might have been obtained during the best hour is to assume a sufficient increase of the area of radiation collected to enable the Erith engine to have been run at its maximum efficiency. The area of radiation collected would thus have been 19,240 sq. ft. The coefficient of atmospheric transmission between 1 and 2 p.m. is 0·679. Hence the available solar heat during that hour would have been—

$$\frac{19{,}240 \times 0{\cdot}679 \times 427}{60} = 93{,}200 \text{ B.T.U. per min.} = 2{,}190 \text{ B.H.P.}$$

The actual power would have been 94.5 B.H.P., or only 4·32% of the available quantity. This seems a terribly poor result until it is compared with the result of the best coal fired boiler and steam engine, the thermal efficiencies of which are 75% and 15% respectively, giving a combined result of only 11·25%.

The corresponding efficiencies of the Shuman Sun boiler and engine under the conditions holding between 2.10 and 3.10 p.m. on 22nd August, 1913, at Meadi, are 40·7% and 10·8%. The reason why the engine had a thermal efficiency of only 10·8% is because being a low pressure engine the temperature range was so small. On the other hand its efficiency compared with that of an ideal engine working on the Rankine cycle was 54·75% when the author tested the low pressure engine at Erith at very nearly the same steam pressure as in Egypt.

The only results of other Sun-power plants which the author has been able to find are those given by Mr. C. G. Abbot, the director of the Astrophysical Laboratory of the Smithsonian Institution, (*The Sun*, p. 369), who states that Mr. A. G. Eneas gave him the following particulars :—

" 14th February, 1901.—Pasadena, California, 11.30 a.m.—0.30 p.m. 642 sq. ft. sunshine. Temperature of air, 61°F Steam pressure, 145—151 lb. sq. in. Steam condensed, 123 lb.

"3rd October, 1903.—Mesa, Arizona. 'About mid-day.' 700 sq. ft. sunshine. Temperature of air, 74°F. Average steam pressure 141 lb. per sq. in. Steam condensed, 133 lb.

"9th October, 1904.—Willcox, Arizona. 11.0—12.0. 700 sq. ft. sunshine. Steam pressure, 148—156 lb. sq. in. Steam condensed, 144·5 lb."

The mirrors of Mr. Eneas's Absorber were arranged in the form of a truncated cone. The boiler was formed of two concentric steel tubes encased in two glass tubes with an air space between them, and between the inner one and the outer steel tube, and was placed at the axis of the cone.

The temperature of the feedwater is not given, but assuming it to be the same as the temperature of the air, we can deduce the rate of absorption per sq. ft. of radiation, and the thermal efficiency of the Absorber. This being done we obtain the following table:—

Place and Date.	Period.	Weight of Steam Produced. lb.	Mean pressure of steam in lb. sq. in. abs.	Rate of absorption per sq. ft. of radiation collected. B.T.U. per hr.	Thermal efficiency of the absorber *
Pasadena, 14th Feb., 1901	11.30 a.m. to 0.30 p.m.	123	163	223	74.6
Mesa, 3rd Oct., 1903.	"about midday"	133	156	219	73.3
Willcox, 9th Oct., 1904	11.0 a.m. to 12.0 noon	144.5	167	238	79 6

* For a maximum transmission of radiation through the atmosphere of 70% and 1.93 calories per sq. cm. per min. as the value of the solar constant.

The remarkable thing about these results is the rate of absorption and the consequent thermal efficiency. Mr. Abbot does not give the dimensions of Mr. Eneas's boiler, but apparently the concentration of solar radiation in his absorber was about 30, and this may account for the high rate of absorption. Eric-

sson used a concentration of 9·2 in his Absorber which he had at work in 1883, but the rate of absorption is not given.

Mr. H. E. Willsie in *Engineering News* of the 13th May, 1909, gives the rates of absorption which he obtained on three occasions with his Absorber at Hardyville, Arizona, in 1902. These rates are stated to have been 120, 122, and 148 B.T.U. per sq. ft. per hour, and that the highest rate was equivalent to a thermal efficiency of 50% $\frac{148}{299} = 49 \cdot 5\%$, so apparently Mr. Willsie knew in 1909 that the maximum available solar heat at the Earth's surface is 299 B.T.U. per sq. ft. per hour. In 1904 he had a plant at St. Louis which used ammonia, and which he states absorbed 377 B.T.U. per sq. ft. per hour, but in giving these figures in the same article he also states that 440 B.T.U. per sq. ft. per hour reached the glass. Thus he seems to have changed from the value of 299 to 440, and consequently gives the thermal efficiency of his St. Louis Absorber as 85%, but we know that the 299 B.T.U. is the correct quantity and $\frac{377}{299}$ gives a thermal efficiency of 126% ! so the 377 looks doubtful.

As will have been seen in the earlier part of the paper, the mean atmos. transmission was taken as 45%, as until quite recently that was the only datum the author had, but he has since utilised Bouguer's formula, and certain information given by Mr. C. G. Abbot in his work entitled *The Sun*, and has elaborated this and put it into graphical form as shown in Figs. Nos. 1 and 12.

Applying Bouguer's formula we find that the transmission to the Earth's solid crust for various zenith distances is as follows :—

Zenith Distance.	Transmission.	
0°	0·700	
10°	0·697	
20°	0·686	
30°	0·658	Mean Transmission 0·599
40°	0·630	
50°	0·577	
60°	0·490	
70°	0·352	

Hence we see the mean transmission is probably 60% over a zenith distance of 70° on each side of the meridian, instead of 45% which was used in the original reports and has been partly used herein. This means that the results of the Shuman Absorbers were compared with a standard which is too low, and that consequently the previously stated thermal efficiencies were too high

With a transmission of 45% and solar constant 2·05 the maximum thermal efficiencies worked out as follows :—

Model ....35·3%
Tacony Absorber ....43·2%
Meadi Absorber ....57·0%

With 70% maximum transmission and a solar constant of 1·93, these efficiencies reduce to :—

Model ....24·1%
Tacony Absorber ....29·5%
Meadi Absorber ....40·7%*

It will now be interesting to compare the actual absorption of useful heat by the Tacony and Meadi Absorbers for different zenith distances, using polar curves for the purpose, and thus making the results comparable with the results given by Mr. Abbot as obtained on Mt. Wilson. It is regrettable that measurements (for different zenith distances and total radiation) do not appear to have been made at the level of Washington, but we shall probably not be far wrong if we reduce the Mt. Wilson results in the ratio of 79·5% to 70·0%, these being the relative transmissions (when the Sun is in the zenith) on Mt. Wilson and at Washington. Hence we should expect the following transmissions at Washington :—

Zenith Distance.	Transmission.	Corresponding maximum quantity of available heat. B.T.U. per sq. ft. per hour.
0°	0 .700	299 .0
20°	0 .686	292 .7
40°	0 .658	280 .8
60°	0 .609	259 .9
70°	0 .564	240 .7
80°	0 .461	196 .5
90°	0 .000	0

From this we see that in considering the thermal efficiency of an absorber, we must take a different standard of comparison for each zenith distance. Thus an absorber of 100% efficiency when in the zenith position would absorb 299 B.T.U. per sq. ft. per hour of useful heat, while the same absorber would still have a thermal efficiency of 100% if it absorbed only 240·7 B.T.U. at a zenith distance of 70°.

Tabulating the actual absorptions of useful heat we obtain the following table :—

* This was obtained between 2·10 and 3·10 p.m.

Absorber.	Date.	Humidity.	Period.	Mean zenith distance during the period.	Percentage absorption = thermal efficiency.
Model at Tacony.	21/8/10	63	a.m. a.m. 11.50—11.55	2° E	24.1
	27/8/10	64	p.m. p.m. 0.20—0.25	6° W	20.9
	27/8/10	54	1.55—2.55	36¼° W	When warming water and *not* producing steam. 34.4
Tacony Absorber.	10/8/11	42	a.m. p.m. 11.16—0.15	3¾° E	29.5
,,	,,	42	p.m. p.m. 0.15—1.15	11¼° W	28.9
,,	,,	42	1.15—2.14	26¼° W	25.1
,,	,,	41	2.14—3.17	41¼° W	17.9
,,	,,	41	3.17—4.18	56¼° W	17.0
,,	12/8/11	58.5	a.m. p.m. 11.17—0.17	3¾° E	27.2
,,	,,	56	p.m. p.m. 0.17—1.18	11¼° W	28.4
,,	,,	53	1.18—2.17	26¼° W	23.7
,,	,,	51	2.17—3.17	41¼° W	19.0
Meadi Absorber.	13/8/13	44	a.m. p.m. 11.30—1.0	3¾° W	36.1
,,	,,	39	p.m. p.m. 1.0—2.0	22½° W	35.4
,,	,,	36	2.0—3.0	37½° W	34.9
,,	,,	31	3.0—4.0	52½° W	32.7
,,	16/8/13	49	a.m. p.m. 11.10—0.10	5° E	17.1
,,	,,	51	p.m. p.m. 0.10—1.10	10° W	17.6
,,	,,	50	1.10—2,10	25° W	19.1
,,	,,	50	2.10—2.55	38¾° W	16.6
,,	22/8/13	40	a.m. p.m. 11.10—0.10	5° E	37.7
,,	,,	37	p.m. p.m. 0.10—1 10	10° W	38.0
,,	,,	35	1.10—2.10	25° W	39.5
,,	,,	36	2.10—3.10	40° W	40.7
,,	,,	33	3.10—4.25	57° W	36.7

With the object of showing that there are better places in Egypt even than Meadi for Sun-power plants, the following figures have been taken from the Meteorological Report for 1910 of the Egyptian Government and give the mean percentages of sky covered with clouds for each month of the year 1910 at Meadi, Assiut, Aswan, Wadi Halfa, and Khartoum.

In reading the figures the entry . . . represents a cloudless sky from sunrise to sunset, and the entry 100, 100, 100 represents a totally covered sky from sunrise to sunset.

The duration of sunshine for the year 1910 was 4% above the average of 7 years, but the figures can be safely taken as the average ones for the succeeding years.

Meadi	is	7	miles	south	of	Cairo	by	River	Nile
Assiut	,,	200	,,	,,	,,	,,	,,	,,	,,
Aswan	,,	500	,,	,,	,,	,,	,,	,,	,,
Wadi Halfa	,,	700	,,	,,	,,	,,	,,	,,	,,
Khartoum	,,	1,550	,,	,,	,,	,,	,,	,,	,,

[See table on page 123.]

METEOROLOGICAL OBSERVATIONS AT MEADI, EGYPT, 1913.

Period—Morning, 10 a.m. to 12 noon.
Afternoon, 1 p.m. to 6 p.m.

1913. July.	Thermometer. Max. °F.	Average °F.	Humidity, Saturation = 100.	Mean wind velocity, miles per hour.	Level of Nile below apex of V notch, FEET.	Remarks.
11th. Mrn....	94	92	29	—	—	Wet and dry
11th. Aft. ...	96	95	22	—	—	bulb thermo-
12th. Aft. ...	102	100	20	—	—	meter hung on
14th. Aft. ...	93	93	37	—	—	East side of
15th. Aft. ...	90	86	37	—	—	outside wall of
16th. Mrn....	88	86	48	—	—	office in shade
18th. Mrn....	93	92	45	—	—	for all readings
18th. Aft. ...	97	96	34	—	—	
19th. Mrn....	94	92	33	—	—	
19th. Aft. ...	97	97	29	6.6 N	—	
21st. Aft. ...	90	88	41	3.9 N	—	
22nd. Mrn. ...	87	85	46	3.8 NNE	—	
22nd. Aft. ...	90	88	43	—	—	
23rd. Mrn....	87	86	55	3.8 NW	—	
23rd. Aft. ...	93	86	43	—	—	
24th. Aft. ...	93	90	40	2.7 N	—	
25th. Aft. ...	92	89	35	—	—	
26th. Mrn....	92	88	33	2.9 NNW	—	
26th .Aft. ...	94	92	32	2.6 NNW	—	
28th. Mrn....	92	89	53	7.6 N	26.14	
28th. Aft. ...	92	86	45	10.0 N	—	Cloudy all day
29th. Mrn....	88	87	51	5.2 NNW	25.97	10% Cloud till 3 p.m.
29th. Aft. ...	91	88	37	6.8 N	—	
30th. Mrn....	83	83	50	2.6 N	25.97	5% Cloud.
30th. Aft. ...	89	88	42	3.4 N	—	
31st. Mrn. ...	83	83	56	4.1 N	25.97	60% Cloud.
31st. Aft. ...	88	87	47	5.5 N	25.97	10% Cloud.

METEOROLOGICAL OBSERVATIONS AT MEADI, EGYPT, 1913.

Period—Morning, 10 a.m. to 12 noon.
Afternoon, 1 p.m. to 6 p.m.

1913. August.	Thermometer. Max. °F.	Average °F.	Humidity, Saturation = 100.	Mean wind velocity, miles per hour.	Level of Nile below apex of V notch, FEET.	Remarks.
1st. Mrn. ...	87	85	54	2 .2	25 .97	
1st. Aft. ...	91	96	40	5 .1	25 .97	
2nd. Aft. ...	102	96	33	1 .9 NE	25 .88	
4th. Mrn. ...	85	84	51	5 .2 N	25 .72	2% Cloud.
4th. Aft. ...	88	88	46	4 .9 N	—	
5th. Mrn. ...	88	85	49	4 .2 N	25 .72	
6th. Mrn. ...	88	87	50	4 .5 N	25 .55	20% Cloud.
6th. Aft. ...	89	88	48	4 .7 N	—	
7th. Aft. ...	91	90	48	2 .8 N	25 .38	15% Cloud
*8th. Mrn. ...	90	88	59	5 .1 NNW	25 .20	No Cloud.
11th. Aft. ...	98	96	41	—	24 .63	
12th. Mrn. ...	91	86	66	—	24 .47	60% Cloud till 10 a.m.
12th. Aft. ...	98	98	43	—	—	
*13th. Mrn...	97	93	45	5 .6 NNW	24 .38	
*13th. Aft....	98	96	37	5 .1 NNW	—	
*15th. Aft....	98	97	40	7 .3 N	—	
*16th. Mrn...	94	92	48	9 .6 NNE	—	
*16th. Aft....	95	94	51	10 .0 NNE	—	
*22nd. Mrn...	94	92	39	3 .9 NNW	—	
*22nd. Aft...	97	96	20	4 .9 NNW	—	
*25th. Mrn ...	87	86	58	7 .3 NE	23 .97	
*25th. Aft....	89	88	59	7 .0	—	
*27th. Mrn ...	88	86	58	6 .0 N	23 .30	60% Cloud.
*27th. Aft....	88	87	58	6 .0	—	10% Cloud.
*28th. Mrn....	88	87	60	4 .0 NW	23 .05	30% Cloud at 10 a.m. 15% Cloud at 11 a.m.
*28th. Aft....	89	87	58	5 .5	—	None in afternoon.
*29th. Mrn....	90	88	60	4 .0 NE	22 .76	
*30th. Aft....	93	92	53	6 .6 N	22 .52	

* Date of a trial of the Sun-Power Plant, from which it will be seen that the meteorological conditions were not above the average on those days. Barometer varied only between 29 .8 inches and 30 inches during the month of August.

The following table is that referred to on page 121 :—

1910 Month.	Meadi.			Assiut.			Aswan.			Wadi Halfa.			Khartoum		
	8 a.m.	2 p.m.	8 p.m.	8 a.m.	2 p.m.	8 p.m.	8 a.m.	2 p.m.	8 p.m.	8 a.m.	2 p.m.	8 p.m.	8 a.m.	2 p.m.	8 p.m.
Jan. ...	36	46	27	.	.	.	4	.	.	.	.	.	3	7	2
Feb. ...	45	51	29	1	1	1	13	4	1	7	.	6	5	5	5
Mar. ...	27	57	31	1	.	.	.	.	.	4	.	.	11	6	4
Apr. ...	25	32	22	.	.	.	.	.	.	1	3	1	7	10	3
May ...	33	51	36	1	1	1	4	.	.	3	6	3	3	9	3
June ...	2	5	7	.	.	.	.	.	.	1	.	.	27	15	18
July ...	9	2	2	.	.	.	.	.	.	.	1	.	37	33	38
Aug. ...	20	4	.	.	.	.	.	.	2	3	5	1	44	34	42
Sept. ...	13	10	3	.	.	.	1	1	2	9	4	2	26	38	31
Oct. ...	18	25	5	1	.	.	.	.	.	1	.	.	7	20	14
Nov. ...	26	26	10	.	.	.	.	.	.	2	8	3	2	5	1
Dec. ...	34	43	22	2	1	1	.	.	.	10	16	5	11	13	6

The Shuman Low Pressure Engine of 1910.

Thus far only the absorbers have been dealt with, but these would be of little value unless some economical means were available of using the low pressure steam produced by them. When Mr. Shuman began to deal with the problem of the utilisation of solar energy, he thought of using the steam to drive an exhaust steam turbine, but inquiries soon showed that such turbines, unless of very large size, are uneconomical. Hence one of his first problems was to design a steam engine which would be economical when using steam at about 1 lb. per sq. in. above atmospheric pressure. In this he was assisted by Mr. E. P. Haines and the measure of their success is plainly shown by the results of the trials, details of which follow.

The investigation and tests of this engine were made at Wissinoming, Philadephia, during the author's visit there from 2nd August to 3rd September, 1910.

Description of the 1910 Low Pressure Engine.

The type of this engine was simple, horizontal, and condensing, the principal dimensions being :—

Diameter of cylinder	24 inches
,, ,, piston-rod.. ..	$1\frac{3}{4}$ in.
,, ,, fly-wheel	6 ft.
,, ,, brake-wheel ..	2 ft. 6 in.
,, ,, crank-shaft ..	3·5 in.
Length of stroke	24 ins.
Ratio of connecting rod to crank	5·5
Clearance volume in per cent. of cylinder volume	1·05 per cent.
Total length of effective edge of each exhaust valve	12·9 ft.

Total area of exhaust ports of one exhaust valve	157·6 sq. in.
Mean movement of exhaust valve to give full opening	1·02 in.
Ratio $\frac{\text{exhaust port area}}{\text{cross section of cylinder}}$	34·8 per cent.
Total length of effective steam edge of each inlet valve	15 in.
Total area of inlet ports of one steam inlet valve	11·25 sq. in.
Movement of inlet valve to give full opening	0·75 in.
Ration $\frac{\text{inlet port area}}{\text{cross section of cylinder}}$	2.5 per cent.
Overall length	16 ft.
,, width	7 ft.
,, height (including separator which is about 3 ft. high)	8½ ft.

1910 Condensing Plant.

The overall dimensions do *not* include the vacuum pumps or the circulating-water pump, as these were not attached to the main engine. A completely separate condensing plant was used, and the results given do *not* include any steam supplied to the condensing plant, but only that passed through the cylinder of the main engine. This was the way Prof. R. C. Carpenter gave his results of testing the same engine, and appears to be the practice in the United States of America, but it must not be forgotten that a condensing plant is *essential* to this engine, and the best English practice in giving results of engine tests is to include the steam used by the condensing plant with that used by the main engine when giving the consumption of steam per horse-power hour. In the first instance the author expected to have to test an engine complete with its own condensing plant, the vacuum pump being driven either by the engine itself, or by a separate engine, the steam supply to which would be separately measured and included in the total steam consumption per horse-power hour. On the first inspection of the engine, however, it was seen (1) that the condensing plant was an entirely separate one ; (2) that instead of the usual English practice of having one air-pump to pump the condensed steam, air and vapour from the condenser, two pumps were employed, one (called the wet vacuum pump) to pump the condensed steam, and one (called the dry vacuum pump) to pump the air and vapour ; (3) that these two pumps were out of proportion to the size of the main engine, being much too large ; (4) that the wet vacuum pump at any rate was of a very uneconomical type ; (5) that in consequence of the facts stated in (3) and (4) it would

have served no useful purpose to test the steam consumption of the two vacuum pumps. Mr. Shuman admitted these were far too large and very inefficient, and said he had used them simply because he had procured them for previous experimental work.

It is common practice in the United States and in England to have a separate condensing plant in the case of a large engine or where a group of engines is in use. In this particular case, where the conditions were so novel, and the engine was not large, it was a little unfortunate that the vacuum pumps were not driven by the main engine, so that the whole steam consumption to produce a horse-power could have been measured, for there was *just a possibility* (in the case of an engine like the one in question, which worked with the steam pressure in the cylinder always below atmospheric pressure) of the dry vacuum pump helping to drive the main engine by means of a leakage of air at atmospheric pressure into the cylinder of the main engine. The effect of this possibility was very fully considered, and an experiment and some calculations were made which proved it certain that no such effect occurred during the tests that would affect the results to any material or practical extent.

Novel Features of the Engine.

The novel features of this engine were confined to the cylinder, the valves, and the valve-gear. Of these the valves were the most important, for they enabled the cylinder clearance to be reduced to one per centum of the volume of the cylinder, which is about half the amount in the best modern engines, and very much less than that in ordinary engines. The exhaust valves were flat steel plates $\frac{1}{8}$ in. thick, equal to the cylinder in diameter, and each had 20 ports radiating from the centre, each port being in the form of a sector tapering from $1\frac{1}{2}$ in. at the circumference to $\frac{1}{2}$ in. at the centre. The movement of the valve was the fraction (about $\frac{1}{40}$) of a rotation in its own plane. This and the size and disposition of the ports produced the desirable effect of a very quick and large valve opening to exhaust.

Steam Valves.

The steam valves were curved ribbed bands of cast iron about 18 in. long and 1 in. wide, and fitted round a portion of the exterior cylindrical surface of each end of the cylinder. They were made to slide parallel to the axis of the cylinder (or to their own width). They, too, were well suited to give a quick admission and cut off of the steam. In the engine tested the area of the inlet ports and the length of steam edge of the valves were very small, but in subsequent designs they have been made considerably larger.

The Steam Cylinder.

The novelty of the cylinder was its simplicity. It had no steam jacket, though it was lagged with cowhair felt and some temporary lagging of the steam chests was used. It had none of the usual ports and passages, the steam being carried to the small steam chests (one at each end of the cylinder) by branching the steam pipe. The valve gear was simple and accessible, and was worked by two eccentrics on the crank-shaft, one of which operated the admission or steam valves, and the other the exhaust valves. The sheave of the eccentric of the steam valves was movable, and was controlled by the fly-wheel governor, which acted by altering the cut-off of the steam valves. The exhaust passages and exhaust pipe were unusually large, and it was obvious everything had been done to reduce the back pressure on the piston to a minimum. There were no novelties in the piston, cross-head, slide, connecting-rod, crank, or crank-shaft. Briefly, the engine might be described as equivalent to a compound engine with the high pressure cylinder removed.

General Opinion.

The essential features of the engine were, in the author's opinion, admirable, simple, sound in theory, practical, cheap in construction and consequently commercial, but he considered that many minor, though necessary, improvements would have to be made. This was the first engine of its kind, and it was only natural and usual that the inventor and designer (Mr. F. Shuman being the former and Mr. E. P. Haines the latter) should have soon realised that many improvements were necessary. The engine had several defects as regards the accessibility of its parts.

The author had the pleasure of stating in his report that his tests, investigations, and results entirely confirmed all that Prof. R. C. Carpenter had stated in his Report, dated 24th February, 1910, to the American Sun Power Company. The methods of, and arrangements for testing were almost identical with those described by Prof. Carpenter in his Report, dated 12th May, 1910, to the American Sun Power Company.

Adaptability of the Engine.

The engine was suitable for use with any supply of low pressure steam, and not necessarily that from a Sun heat absorber. It was also suitable for purposes other than irrigation. Its essential features were applicable to high pressure engines as well as low, though this particular engine was designed for low pressures and could not be used for even moderately high pressures (say 60 lb. per sq. in. by gauge) without structural alteration of the valve gear and a general strengthening of the parts.

Indicated Horse-Power.

With regard to the indicated horse-power, it will be noticed that this is not given in the tabulated results of the trials, nor did Prof. Carpenter give it in his first Report, but in a supplement $2\frac{1}{2}$ months later. Indicator cards similar to those obtained by Prof. Carpenter were taken during all the trials except No. VI. (Trial No. VI. was made because for some unexplained reason the results of Trial No. II., though very steady, would not plot well with the other results, while on repeating in Trial VI. the conditions of Trial II., results concordant with all the other trials were obtained), but after carefully considering the matter the author came to the conclusion that very little reliance was to be placed on cards obtained under such conditions and consequently he did not attempt to work them out. By the use of optical indicators possibly reliable results might have been obtained. Briefly the difficulty was that the steam pressures being so low the effects of indicator friction and inertia became very serious and made the indicator results unreliable, though the diagrams were useful for the purpose of valve-setting. Fortunately however, the indicated horse-power is not very important commercially, its chief use being to enable the mechanical efficiency to be obtained. That this must have been high is implied by the low steam consumption, which, of course, is of great commercial importance.

Results of the trials of 1910 Low Pressure Engine.

With regard to the results of the trials, only a few points need special comment. In giving the total quantity of condensed steam, account has been taken of the correction for the hot-well level, which was necessary only in Trials II. and VI. and amounted to 4.6 lb. as a maximum. Account has also been taken of the condensed moisture collected from the discharge from the dry vacuum pump, which varied from 31·2 lb. in Trial II. to 4·3 lb. in Trial IV.

RESULTS OF THE TRIALS OF THE 1910 SHUMAN (SINGLE PISTON) LOW PRESSURE ENGINE.

TRIAL NUMBERS	I.	II.	III.	IV.	V.	VI.
Duration in hours ...	5	5	1 .5	2	2	2
Barometer in inches of of mercury	30 .286	30 .049	30 .202	30 .200	30 .180	30 .212
Steam pressure in in. of mercury	2 .11	13 .42	13 .44	2 .06	2 .00	13 .64
Steam pressure in lb. per sq. in. abs.	15 .89	8 .18	8 .23	15 .83	15 .79	8 .14
Vacuum in in. of mercury	28 .07	27 .85	27 .83	27 .87	27 .84	28 .07

TRIALS OF THE 1910 SHUMAN ENGINE—cont.

Trial Numbers	I.	II.	III.	IV.	V.	VI.
Pressure in condenser lb. per sq. in. abs....	1.09	1.08	1.16	1.14	1.15	1.05
Temperature corresponding to press of steam °F.	216.0	184.0	184.2	215.8	215.7	183.1
Temperature of steam as measured °F.......	222.2	184.9	184.9	216.5	216.5	185.6
Temperature corresponding to condenser pressure °F.	105.0	104.6	107.0	106.3	106.7	103.5
Temperature of exhaust steam as measured °F..........	101.5	102.3	104.3	104.0	107.2	100.2
Temperature of engine room °F.	83.6	84.4	77.6	80.1	81.7	88.7
Temperature of external air °F.	77.9	79.0	74.5	76.2	75.4	87.4
Total quantity of condensed steam in lb.	3,924	2,555	523	1,041	331	889
Quality of steam; °F. of superheat	6.2	0.9	0.7	0.7	0.8	2.5
Net brake load in lb.	185.0	90.0	45.0	92.5	0	77.5
Revolutions per min....	160.2	129.6	129.1	158.7	163.2	126.8
Brake Horse Power ...	29.6	11.7	5.8	14.7	0	9.8
Condensed steam discharged per B.H.P. hour in lb.	26.5	43.8	60.0	35.4	infin.	45.2
Head over orifice for circulating water in ft.	0.558	0.496	0.469	0.537	0.527	—
Total quantity of circulating water in lb.	365,500	341,750	99,750	142,300	141,000	—
Quantity of circulating water per B.H.P. hour in lb.	2,452	5,870	11,460	4,840	infin.	—
Quantity of circulating water per lb. of condensed steam in lb.	95.7	133.8	190.7	136.7	434.0	—
Temperature of circulating water, inlet °F.	76.6	76.3	75.9	76.1	75.9	—
Temperature of circulating water, outlet °F.	86.5	83.0	80.4	82.5	77.9	81·5
Rise of temperature of circulating water °F.	9.9	6.7	4.5	6.4	2.0	—
Quantity of heat per B.H.P. hour discharged in circulating water in B.T.U.	24,270	39,320	51,600	31,000	infin.	—
Total heat of steam per lb. from temperature of condenser in B.T.U.	1081.8	1067.2	1064.8	1077.8	1077.4	1068.6

TRIALS OF THE 1910 SHUMAN ENGINE—cont.

TRIAL NUMBERS	I.	II.	III.	IV.	V.	VI.
Total heat supplied to engine per B.H.P. min. reckoned from the temperature of the condenser in B.T.U.	477	778	1,063	637	infin.	806
Heat discharged in circulating water per B.H.P. min in B.T.U.	404 .5	655 .3	860 .0	516 .7	infin.	—
Heat converted into work per B.H.P. min. in B.T.U.	42 .5	42 .5	42 .5	42 .5	0	42 .5
Heat lost in radiation and conduction and unaccounted for per B.H.P. min. in B.T.U.	13	80	160	78	—	—
Thermal efficiency per cent.	8 .90	5 .47	3 .99	6 .67	0	5 .27
Efficiency of a perfect engine working between the same limits of temperature per cent. (Carnot cycle)	17 .15	12 .87	12 .10	16 .30	—	12 .92
Relative efficiency per cent.	51 .9	42 .5	33 .0	40 .9	0	41·6
Efficiency compared with an engine working on the Rankine cycle	52 .7	43 .7	—	—	—	—

The steam in all cases showed a slight amount of superheat in spite of various attempts which were made to prevent superheating. The reason for this was that instead of being able to supply the engine directly with a large volume of low pressure and even wet steam, such as it would receive in practice when utilising the exhaust steam from other engines, it was supplied with the exhaust steam from the dry vacuum pump, and this quantity being insufficient it was supplemented by a live steam supply reduced by throttling from a pressure of about 90 lb. per sq. in. to 1 lb. per sq. in. There was only one steam boiler available, and its steam pressure had to be high in order to supply the steam driven vacuum pumps. Such a big reduction of pressure by throttling was bound to superheat the steam. After Trial I. further to reduce the superheating, the live steam was made to discharge *below* the water level in the separator, and thereafter the amount of superheat was quite small. The quantity of circulating water used per lb. of condensed steam was enormous. This was partly due to the high temperature of the circulating water on admission to the condenser, and partly

because no attempt was made (as the "head over the orifice" shows) by Mr. Shuman's staff (who had charge of the *running* of the engine, while the author's own and independent staff did the testing) to reduce the quantity when the power was reduced. The quantity of circulating water (which gravitated through the condenser) does not of course affect the steam consumption. It is merely one of the necessary requirements for producing a vacuum.

Thermal Efficiencies. The thermal efficiencies of the engine appear very low until they are compared with the corresponding efficiencies of a *perfect* engine (Carnot cycle) working between the same limits of temperature. The maximum relative efficiency of 51·9 per cent., when the B.H.P. was 29·6, compares favourably with 52 per cent., the relative efficiency of a *compound* condensing engine (at the Central Technical College, University of London) developing 26·64 B.H.P. which was about two-thirds of its full power. A *triple* expansion condensing engine (at the Massachusetts Institute of Technology) developing 120 H.P. (? Brake), its full capacity being 125 H.P., had a relative efficiency of 73·6 per cent.

Comparison of results. An interesting and important comparison is to consider the results obtained from the Shuman Low Pressure engine with those obtained by Prof. Carpenter from the low pressure cylinder only (74 in. diameter, 60 in. stroke) of a triple expansion pumping engine at Milwaukee designed by Reynolds and built by the E. P. Allis Company. The total indicated horse-power of the whole engine (three cylinders) was 574, of which 229 was developed in the low pressure cylinder. The pressure of the steam supply to this low pressure cylinder was 1·3 lb. per sq. in. above atmosphere. The steam consumption per indicated horse-power by the low pressure cylinder was 29·6 lb. per hour = 32·6 lb. per brake horse-power hour. The thermal efficiency was 7·2 per cent., that of a perfect engine working between the same limits of temperature 18·7 per cent., and the relative efficiency 38·6 per cent. The corresponding quantities for the Shuman engine of only 29·6 B.H.P. (with a slightly lower steam pressure and not quite such a good vacuum) were 26·5 lb. of steam per B.H.P. hour; thermal efficiency 8·90 per cent.; thermal efficiency of perfect engine 17·15 per cent.; relative efficiency 51.9 per cent.; or compared with an engine working on the Rankine cycle the relative efficiency was 52·7%.

Steam Consumption. The best consumption of 26·5 lb. of steam per B.H.P. hour is better than Prof. Carpenter's best result of 28·8 lb. per B.H.P. hour, and was due to the maximum B.H.P. of the author's set of trials being greater than the maximum of Prof. Carpenter's, for on plotting the results (*vide* p. 131) it is seen that the reduced con-

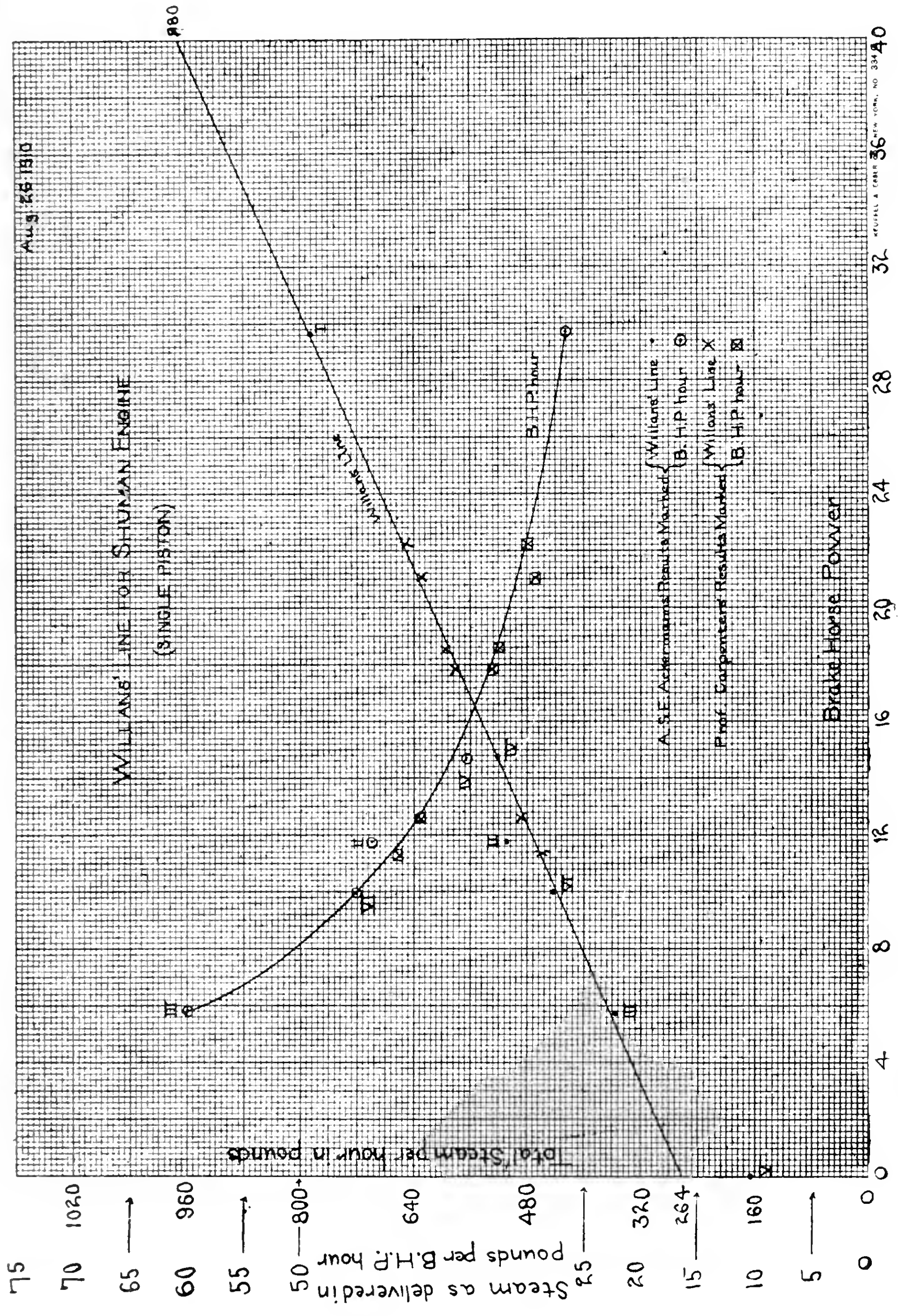

FIG. 14.

WILLANS' LINE FOR THE SHUMAN 30 B.H.P. LOW PRESSURE ENGINE OF 1910.

sumption is exactly what it should be to be consistent with the increased B.H.P. The steam consumption does not include gland leakage, because the steam discharged by the engine was measured and not the feed water to the boiler, the latter method being impracticable in this case. In high pressure engines, gland leakage may amount to 10 per cent. of the total quantity of steam, but in this low pressure engine the leakage would be practically nil, if indeed (as has been dealt with earlier herein) it were not a negative quantity, *i.e.*, air might leak in, instead of steam out.

The Shuman High and Low Pressure Engines of 1911.

The author's visit to Philadelphia from 22nd July to 31st August, 1911, was for the purpose of testing and reporting on the above and upon the 1911 design of Absorber which was arranged to supply Sun generated steam to the Low Pressure engine. This 100 H.P. Low Pressure engine, however, was never tested because the arrangements made before the author's arrival for such testing, were, in his opinion, in the most essential details utterly unsuitable for, and incapable of, giving reliable results.

The chief objections were the methods of measuring the steam used and the power developed, and the inadequate supply of steam. The faultiness of the arrangements for measuring the steam was very easily remedied, as was done by August 10th, but most unfortunately it was not until August 22nd that arrangements for the proper measurement of the power were begun. These were completed by the evening of Monday, 28th August, and everything was ready for tests on Tuesday and Wednesday—if the Sun shone! but he did not, and instead there were heavy clouds and rain. Even had those two days been bright, the tests would not have been satisfactory, because while the engine was designed to develop 100 B.H.P., the maximum steam supply (from the Sun Heat Absorber) would probably have been sufficient to develop only 35 B.H.P.

Description of the High Pressure Engine of 1911.

Six short but very interesting trials of the 30 B.H.P. high pressure engine were made and the results have been included herein because the question has been frequently asked whether the principles which have been found so economical in the case of the low pressure engine, could not also be applied to a high pressure one.

This engine had a single cylinder 9 in. diameter, a 24 in. stroke, a single piston, and combined steam-jacket and steam-chest. The stroke was not intentionally made so long, but the same crank-shaft, crank, connecting-rod and piston rod were used (for the sake of cost) as were used for the 24 in. × 24 in. low pressure engine. The admission and exhaust valves were of the

High Pressure Engine with Duplex Piston.

same pattern as those of the contemporary 30 H.P. Low Pressure engine. The valve gear was nearly the same, but was more complicated for the sake of using some existing parts. The objects of the tests were to determine whether the steam consumption of this engine was more or less than that of an engine similar, but having a duplex piston. The results show unmistakably that the duplex piston high pressure engine, was more economical than a single piston high pressure engine, the steam consumption per B.H.P. hour when working non-condensing being 7·2% less, and 8·9% less when working condensing. This fact is shown by the following results :—

Type of Engine.	B.H.P.	Steam pressure lb. sq. inch by gauge.	Steam consumption per B.H.P. (excluding steam for condenser plant).	Thermal efficiency compared with an engine working on a Rankine cycle.
			lb.	%
Single Piston ... High Pressure Non-Condensing	27 .85	100	25 .65	64 .1
Duplex Piston High Pressure Non-Condensing	29 .00	95	23 .80	71 .7
Single Piston ... High Pressure Condensing ...	27 .81	98	18 .06	45 .9
Duplex Piston High Pressure Condensing ...	22 .82	96	16 .45	50 .3

All the results just given are extremely good. For so small an engine of any ordinary design the steam consumption would be at least 35 lb. of steam per B.H.P. hour when working non-condensing. No steam was admitted to the inter-piston space.

Low Pressure Engine with Duplex Piston.

It may be recorded here that in 1910 when the single piston Low Pressure engine was tested, the author also tested a 24 in. × 24 in. 30 H.P. low pressure engine having two pistons rigidly attached to the same piston rod. Boiler steam was admitted to the inter-piston space, in fact this space was the steam "chest" for the pistons had the steam valves in them, and thus the live steam was so to speak left behind the piston in its stroke. The arrangement acted as a hot plug of steam and heated the cylinder walls from the *inside*

where the heat is most wanted. The author was very pleased with the arrangement, but the steam consumption was greater than that of the 24 in. $\times$ 24 in. single-piston engine the results of the trials of which have already been given. It was not proved that this hot plug arrangement is not an advantage, for it was afterwards found that the radial disc steam valves of the duplex piston engine caused a great deal of friction, and this may have accounted for the slightly larger steam consumption of this engine.

THE 100 H.P. LOW PRESSURE ENGINE OF 1912.

Description of the Low Pressure Engine of 1912.

This engine was constructed at Erith by MM. Fraser and Chalmers, under the supervision of Mr. Walrond and the author. It had a 36 in. cylinder and 36 in. stroke, and a duplex piston, but no steam was supplied to the inter-piston space.

DuplexPiston.

The object of the two pistons (which were rigidly fixed to the single piston rod) was to cause about $\frac{1}{3}$ of the total length of the cylinder (for the distance between the pistons was 3 ft. 6 in.) to be always subject to the heating effect of the jacket steam without the corresponding portion of the cylinder walls being subject to the cooling effect of being connected to the condenser. By this arrangement the mean temperature of the cylinder walls was higher than it would have been if there had been but one piston, and hence the cylinder condensation was less. Further to prevent cylinder condensation, the ends of the cylinder and the heads of the 12 exhaust valves were insulated with a layer of vulcanised rubber $\frac{1}{16}$in. thick fixed to a mild steel plate $\frac{1}{16}$in. thick by Bakelite varnish. These compound plates were then screwed to the exhaust valves and the cylinder heads.

Oil Seals.

To prevent air leaking into the steam spaces (the pressure in most of these was below that of the atmosphere) which would have caused a poor vacuum and given the dry vacuum pump more work to do, all glands on the steam spaces were oil-sealed, *i.e.*, an annular channel was cut in the gunmetal gland and this was connected by a small pipe to a tank overhead containing thick cylinder oil, so that instead of a large quantity of air leaking in, only a small quantity of oil had to be dealt with, and this was used over and over again, after being strained.

Jacket.

The jacket also acted as the steam-chest, consequently the jacket drain also discharged any condensation from the short length of steam pipe. This condensed steam was included in the steam consumption, and was a remarkably small quantity.

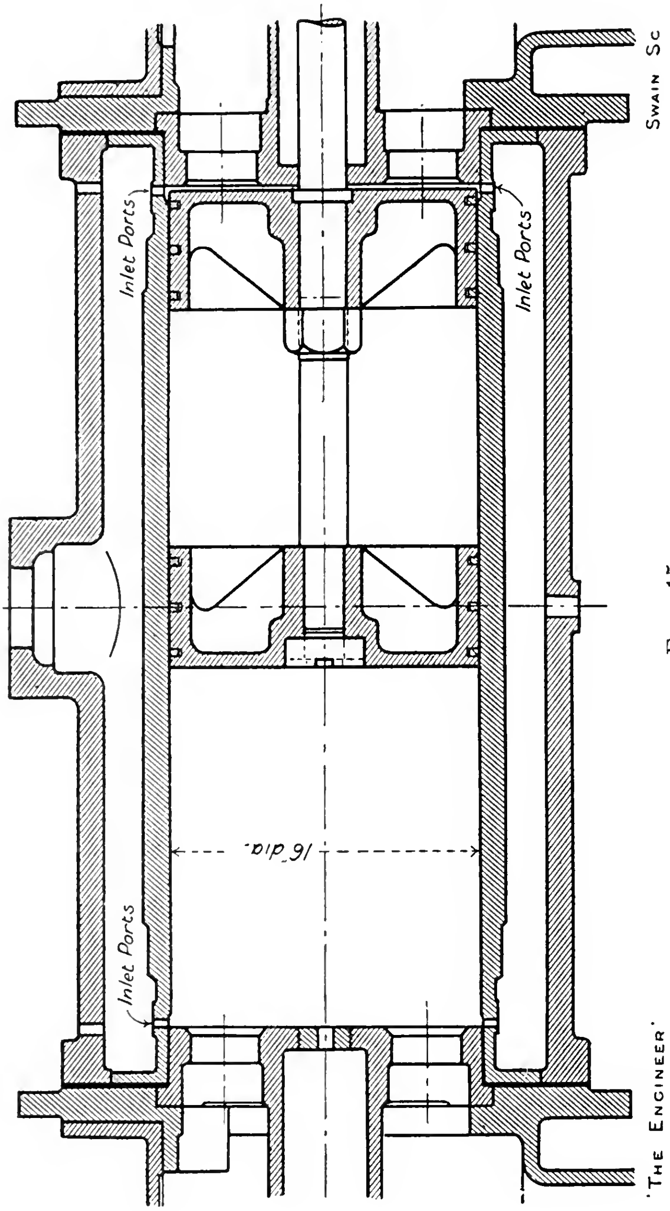

Fig. 15. Shuman Low Pressure Engine, 1912. Longitudinal Section of Cylinder.

Condensing Plant.

There was nothing particularly novel about the condensing plant, but the engine requires a really good vacuum if it is to give its best results. There is no hardship or loss in this, seeing that a 28·5 in. vacuum can be obtained by an expenditure of only 2% of the total power when this is 100 H.P. The condenser was a "Contraflo" one having 500 sq. ft. of cooling surface, and it behaved excellently.

Vacuum Pumps.

The vacuum pumps were specially designed, which was a mistake, and there was a considerable amount of trouble with them at first. The displacement of the dry vacuum pump per lb.

of steam condensed was 1·70 c. ft., which is large, and it was found that beyond a certain displacement, a further increment did not improve the vacuum, nor did such further increment seem to increase appreciably the consumption of electrical energy by the motor driving the vacuum pumps.

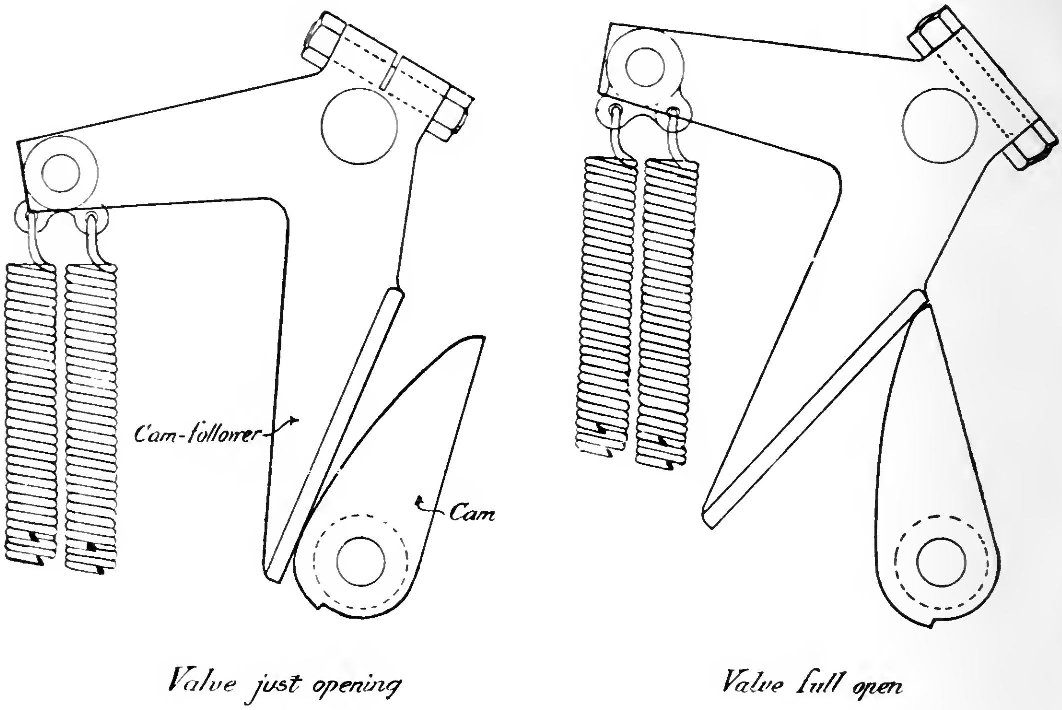

FIG. 16.

Valve gear. The valve gear was simple, accessible and ingenious. It was practically the same for the steam valves as for the exhaust valves. The valve-rods oscillated parallel to their length and actuated short levers which in turn caused the cams to oscillate. The profile of the cams was something like an involute curve and the cams were centred at what would be the centre of the generating circle of the involute. The cams were in contact with the cam-followers, which were similar to the cams in their general form and motion, but instead of having a curved profile, the part on which the cam acted was straight, and the centre of oscillation of the cam-follower was remote from the centre of the cam, so that the heel of the cam acted on the tip of the cam-follower and (at the end of the motion) the tip of the cam acted on the root of the cam-follower. Two very desirable results were thus obtained :—(1) when the cam was starting to move the valve, the leverage was in favour of the cam as regards force, and (2) when the valve was opening (remembering there was lap in the case of the steam valves), the tip of the cam acted on the root of the cam-follower, and thus gave a very quick motion to the valve.

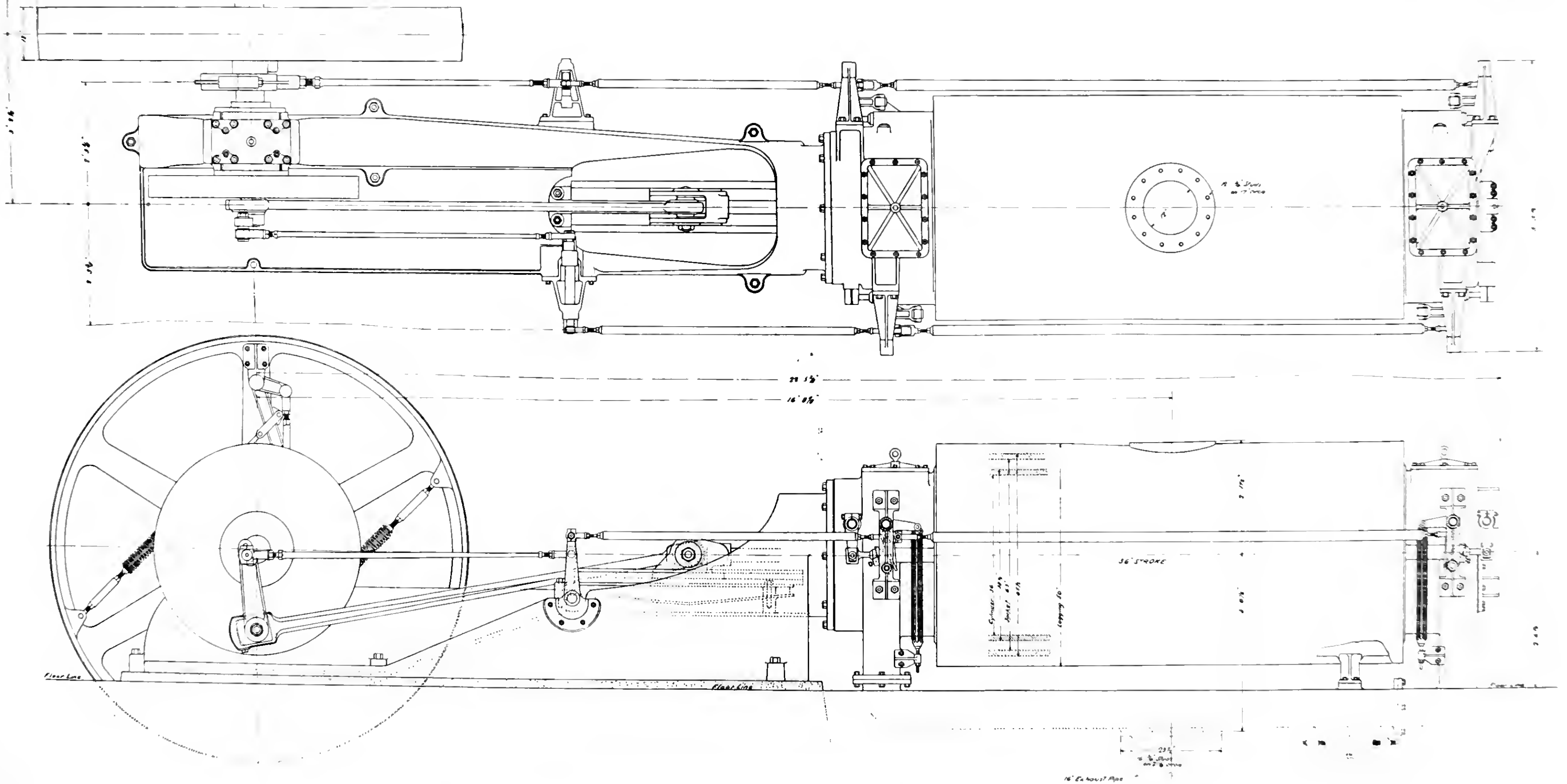

Fig. 17.
Assembled Engine.

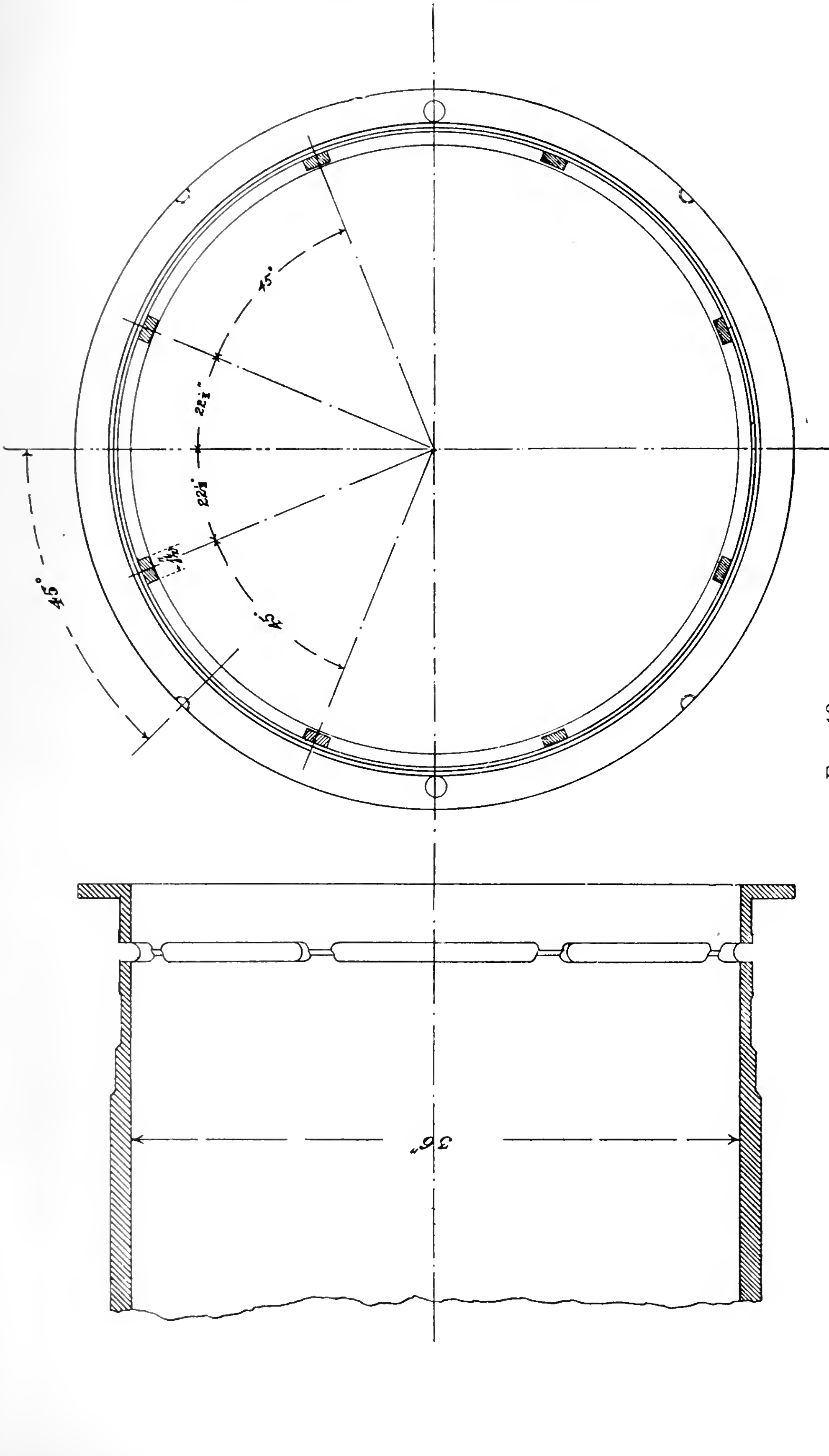

FIG. 18.
SHUMAN L.P. ENGINE. CYLINDER AND PORTS.

Steam Ports and Valves.

The steam ports were a series of long openings completely encircling each end of the cylinder, and the steam valves were curved strips of cast iron, one to each port, which together made up nearly a complete ring right round the outside of the cylinder. They were held in a circular valve-carrier, each valve having a small arc-shaped spring at its back, and moved parallel to the axis of the cylinder.

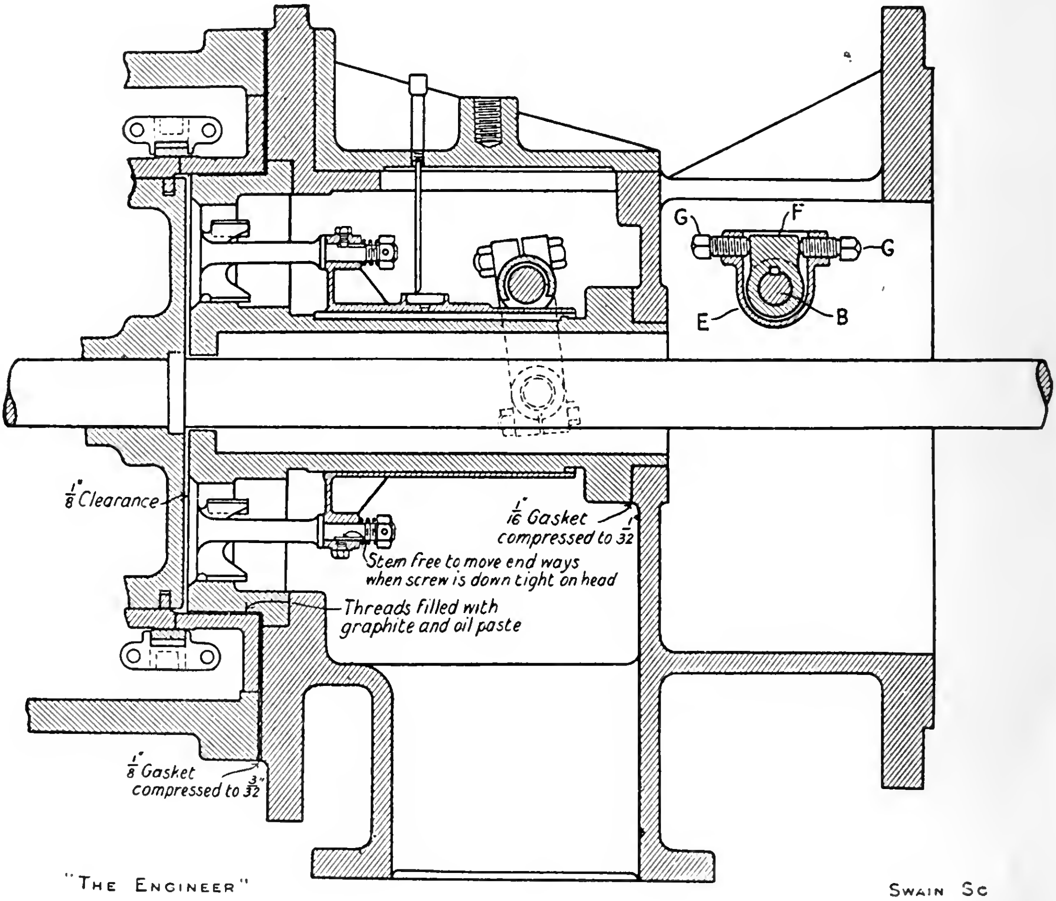

Fig. 19.

Shuman Low Pressure Engine, 1912. Vertical longitudinal section of crank end of cylinder.

Exhaust Valves.

The exhaust valves consisted of a group of six mushroom valves at each end of the cylinder opening inwards and simultaneously. The diameter of each valve was $8\frac{3}{8}$ in.

The engine used in Egypt was made in 1911, but the description which has just been given applies to it as well, except that the Egyptian engine had only one piston.

The best trial of the Low Pressure engine at Erith gave the following results :—

Steam Pressure in. lb. sq. in. abs.	Vacuum Inches of Mercury	Barometer ins.	Revolutions per minute.	B.H.P.	Steam per B.H.P. hr. lb.	Thermal efficiency compared with a Rankine cycle.
16.2	28.4	29.5	100	94.5	22.1	54.75%

It was found that the power taken to drive the wet and dry vacuum pumps of this engine when developing about 100 B.H.P. was practically 2 H.P. For comparison with the results of the engine trials the following figures are given :—

Steam Consumption of Various Engines.

There appear to be very few results published of trials of very low pressure engines or turbines.

It is not stated whether the steam consumption of the condensing plant is included in the following results. The author is of opinion it is not, and that therefore the results are comparable with those of the Shuman engines except for the fact that they are mostly for very much larger units, and higher pressures, than the latter. Consequently the comparison does not do full justice to the Shuman engines.

Description.	B.H.P.	Steam Press. by Gauge. lb. sq. in.	Steam per B.H.P. Hour. lb.	Absolute press. in lb. per sq. in. in condenser equivalent to the vacuum.
Rateau Steam Turbine, high and low pressure combined. Trans., A.S.M.E., 1904, p. 295 ...	500	12	15.8	—
Rateau Steam Turbine, high and low pressure combined. Trans., A.S.M.E., 1904, p. 801 ...	388	155	19 2	2.85
Rateau Steam Turbine, high and low pressure combined. Trans., A.S.M.E., 1904, p. 808 ...	89	82.5	34.6	2.55
Rateau Steam Turbine, high and low pressure combined. Trans., A.S.M.E. 1904, p. 817 ...	300	atmos.	38.5	2.57

Description.	B.H.P.	Steam Press. by Gauge. lb. sq. in.	Steam per B.H.P. Hour. lb.	Absolute press. in lb. per sq. in. in condenser equivalent to the vacuum.
Parson's Turbine at Lots' Road, Chelsea. "Power," 15th and 22nd March, 1910, p. 531 ...	8,000	180 (?) & 140°F. (?) superheat.	10 .2	1 .13
Curtis Turbine, Philadelphia Rapid Transit Co. "Mech. Eng." 20th Jan., 1906, p. 105 ...	1,000	atmos.	guarantee. 36 .0	0 .98
Ditto	1,000	,,	guarantee. 45 .0	1 .96
Parsons' Turbine at Newcastle. "Engineering," vol. lvi., p. 126	165	97 .1	20 .3	0 .75
Low pressure cylinder of triple expansion condensing pumping engine at Milwaukee, tested by Prof. Carpenter ("Engine & Boiler Trials," by Prof. Thurston), p. 590	208	1 .3	32 .6	0 .7
The following results are from "Engines & Boilers," by W. W. Pullen :—				
Simple non-condensing	134	96	22·00	—
Dujardin *Compound* Condensing... ...	548	90	13 .46	—
Sultzer *Compound* Condensing... ...	247	85	13 .35	—
Wheelock *Compound* Condensing... ...	590	160	12 .84	—
McIntosh & Saymore *Compound* Condensing	1,076	128	12 .76	—
Leavitt *Compound* Condensing... ...	643	135	12 .16	—
Sultzer *Triple* Expansion	615	141	11 .70	—
Reynolds *Triple* Expansion	574	120	11 .68	—
Snow *Triple* Expansion	773	156	11 .26	—
Leavitt *Triple* Expansion	576	185	11 .22	—
Nordberg *Quadruple* Expansion	712	200	12 .26	—

Description.	B.H.P.	Steam Press. by Gauge. lb. sq. in.	Steam per B.H.P. Hour. lb.	Absolute press. in lb. per sq. in. in condenser equivalent to the vacuum.
Engine at Central Technical College, London. Exper. No. 34, Compound engine, Feb. 4th, 1892 ...	26.64	75.8	23.5	3.37
Ditto, Exper. No. 35, Compound engine, Feb. 4th, 1892 ...	31.05	89.72	22.4	3.68
Curtis Turbine, Philadelphia Rapid Transit Co. "Power & the Engineer," May 4th, 1909	1,078	14.53 abs.	33.7	1.30
Shuman low pressure engine, single piston	29.6	15.89 abs.	26.5	1.09
Ditto, duplex piston	94·5	16·20 abs.	22·1	0·54
Shuman H.P. engine, single piston, condensing	27·81	98·0	18 06	0·73
Ditto, duplex piston, condensing	22·82	96·0	16·45	—

STEAM CONSUMPTION OF CONDENSING PLANTS.

Test by Twining & Kerr (*Power and the Engineer*, May 4, 1909, p. 791.)

Horse-Power of exhaust steam turbine		1073·0
,, ,, ,, dry vacuum pump	9·94	
,, ,, ,, wet ,, ,,	0·73	
	——	10·67
Ratio of H.P. of condenser pump to H.P. of turbine		1%

The C. H. Wheeler Mfg. Co., of Philadelphia (well-known makers of condensing plants), writing on 29th August, 1910, said that to remove from a condenser the steam received from a 900 B.H.P. engine using 26·5 lb. of steam per B.H.P. hour would require 15 B.H.P. delivered to the vacuum pump.

This is equal to 1·67 per cent. of the engine power.

For another type of vacuum pump they claim it takes only 0·89 per cent.

Allen, on Surface Condensing Plant, Proc. I. C. E., 1905, Vol. 161, p. 184, found that for only a 25 in. vacuum the vacuum pump took 2·8 per cent. of the total H.P., or 7·5 per cent. of the total steam. The fact that the pump took a greater proportion of steam than its power seems to warrant, is because the smaller engine used for driving the vacuum pump is less efficient as regards steam consumption than the main engine; an argument for driving the vacuum pump by the main engine.

The Trials of the combined Plant in Egypt, 1913.

All concerned were greatly looking forward to the results of the trials of the complete Sun-power plant as erected at Meadi on the Nile, about 8 miles from Cairo. The low pressure engine, auxiliaries, condenser, and irrigation pump were the same as those erected in Tacony in 1911. The Absorber was entirely new and is described on p. 101, *et seq.*

Arrangements for the Trials.

As the arrangements for any of the trials herein recorded have not been described, it may be well to give a brief description of those for the Egyptian trials, and those for the trials of the two Shuman engines (100 H.P. High Pressure and 100 H.P. Low Pressure) which were constructed at Erith, for, as it will have been seen under the heading "Shuman-Boys' Absorber of 1913," it turned out that in order to get an equitable overall result for the Egyptian plant, the steam consumption of the Low Pressure engine at Erith had to be combined with the steam production of the Egyptian Absorber.

Irrigation Pump.

The irrigation pump was double-acting, the plunger being 28 in. in diameter, and the maximum stroke 28 in. Owing to the steam supply being smaller in the morning and in the evening than at mid-day, it was necessary to make arrangements for varying the stroke of the pump without stopping the engine. This was done in the following manner. The crank-pin driving the pump was attached to a slide working in a slot in the disc-crank, the slot being coincident with a diameter of the disc. The slide also acted as a form of nut on a square-threaded screw running along the slot, so that when the screw was turned one way, the slide and crank-pin were moved further from the centre of the disc-crank, that is, the stroke of the pump was increased. When the screw was turned in the other direction, the stroke was reduced. To one end of the screw, which projected slightly beyond the rim of the disc-crank, a star-wheel was fixed, and on the ground just underneath the disc-crank there were two short pins placed in a line parallel to the shaft of the disc-crank. Either one or other (or neither) of these pins could be raised by a lever, and when a pin was so raised the star wheel engaged with it and caused the screw to

rotate. The other pin caused the rotation to be in the opposite direction.

The irrigation pump drew its water from the Nile. The delivery main had the surface condenser connected to it as a shunt. The whole of the water was then discharged into a weir-tank of special form designed by the author. The conditions to be provided for in this tank were that in the morning and evening, when the output of steam was expected to be comparatively small, the quantity of water to be gauged would be small, and to measure this accurately a right-angled V notch was desirable, as a rectangular weir is not reliable for heads of less than 6 in. (or more than 18 in.). After considering several other schemes it was decided to have a rectangular weir 5 ft. wide with a sharp gunmetal edge, and a frame containing a V notch. The frame was made to slide in vertical grooves over the ends of the rectangular weir, and had a seating of indiarubber along its bottom edge for the double purpose of protecting the knife edge of the rectangular weir and of making a water-tight joint with it. The down-stream sides of the grooves were also fitted with rubber to make tight joints, and the V notch could take any head over its apex from zero to 18 in., so that when the latter limit was reached, and the quantity of water was increasing, the frame with the V notch was slid out and the head then over the rectangular weir was about 6 in. Conversely, when the quantity was falling, the V notch was put back again as soon as the head over the rectangular weir had fallen to about 6 in. The difference in the zero readings of the two weirs was 4·1 in.

Weir-tank. Fig. 20.

Attention is called to the hook-gauge, also specially designed, as no simple or cheap form could be purchased, which had the convenience of a fixed pointer for the readings. Where the pointer moves, it means the observer has to hang more than half upside down over the side of the tank to take low readings. When the observer is on the shady side of forty and weighs nearly 13 stone, this is inconvenient !

Hook-gauge. Fig. 21.

The suction level was measured by a rod from the top of the steel sump in the Nile, and rarely varied more than a 2 in. rise in 24 hours. The levels from the top of the sump to the top of the rectangular weir and the bottom of the V notch were taken carefully once and for all by means of an engineer's 14 in. level. Stakes were put in along the gradually sloping right bank of the Nile and a scale was fitted in turn to these and zero readings taken, so that had the water risen above the top of the sump, the scale would have been shifted from stake to stake as the water rose, for it would then have been inconvenient and unsafe to wade out to take readings at the sump. As a matter of fact these stakes were never used, for 1913 saw what is officially

termed a "low Nile." Thus the pump horse-power was measured; and by counting the number of strokes of the irrigation pump, and at the same time taking readings of the head over the weir, the slip of the pump was determined. This varied from 19 to 35% according to speed and stroke, partly because the valves were few and large, and their lift high. The author was afterwards informed that when the pump was opened up, one of the valves was found to be misplaced. With this result alone it will be seen how unfair it would have been to the Sun-power scheme as such to have recorded officially the overall results of the whole plant. But the pump was not the only thing at fault with the engine end of the plant. On testing the steam valves they were found to leak badly, though the exhaust valves were found to be tight. The piston was also suspected of leaking, but this could not be determined because of the leaky steam valves. Great difficulty was experienced in obtaining a good vacuum, which is so essential for the economical working of the Shuman engine. When the auxiliary plant is in good order, a good vacuum costs only 2% of the total power. Much time was taken to improve the vacuum and with some success. After several of the trials had been made it was found that the condenser was nearly full of the fine mud which settles out of the Nile water and that many of the tubes were blocked by fish which had become jammed in the inlet ends. Even when these obstructions had been removed the results were not very satisfactory, partly because the arrangement of the shunt pipes for supplying water to the condenser was not good, and partly because the weighted flap valve on the main delivery pipe, which was supposed to cause some of the water to pass through the condenser, failed to act. To screen off the fish is an easy matter. The silting up of the condenser is a far more troublesome problem. The author suggests that the condenser should have a large pocket in the water space, below the tubes, in which the mud could be collected and removed from time to time. Vertical condenser tubes are not very efficient, otherwise if the condenser were placed vertically, with the circulating water outlet at the bottom, no doubt it would keep free from silt. 40 lb. of the water contained as much as $\frac{1}{4}$ lb. of mud. This was measured in case the quantity might have justified an allowance being made when calculating the pump horse-power.

Slip of Pump.

Testing the Steam and Exhaust Valves.

Condenser Clogged.

The condensed steam from the hot well pump was discharged into two barrels alternately, each being on a Denison platform weighing machine, both of which were checked with standard weights several

Condensed Steam.

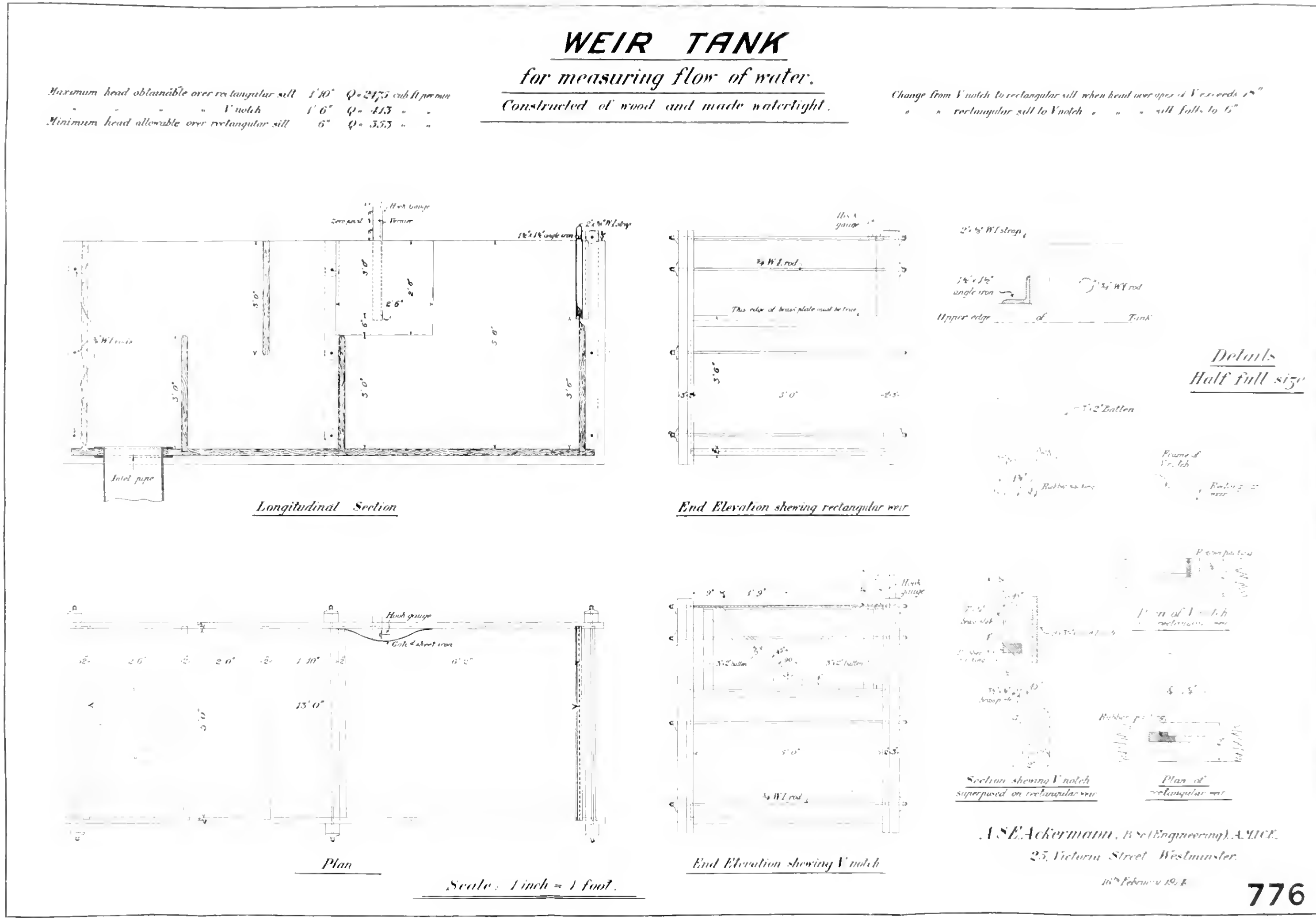
WEIR TANK
for measuring flow of water.
Constructed of wood and made watertight.
Maximum head obtainable over rectangular sill 1' 10" Q = 2475 cub ft per min
" " " " V notch 1' 6" Q = 413 " "
Minimum head allowable over rectangular sill 6" Q = 353 " "
Change from V notch to rectangular sill when head over apex of V exceeds 18"
" " rectangular sill to V notch " " " sill falls to 6"
Hook Gauge
Vernier
Zero point
1½" x 1½" angle iron
2" x ⅜" W.I. strap
Inlet pipe
Longitudinal Section
¾ W.I. rod
This edge of brass plate must be true
End Elevation shewing rectangular weir
Upper edge of Tank
angle iron
Details
Half full size
Batten
Rubber washer
Frame of V notch
Hook gauge
Galvd sheet iron
13' 0"
Plan
End Elevation shewing V notch
Section shewing V notch superposed on rectangular weir
Plan of rectangular weir
Plan of V notch
Scale: 1 inch = 1 foot.
A. S. E. Ackermann, B.Sc. (Engineering), A.M.I.C.E.
25, Victoria Street, Westminster.
16th February 1914
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Fig. 20

times during the trials. Some condensed steam was discharged with the sealing oil used in the dry vacuum pump. This was collected, weighed, and added to the other. The discharge from the dry vacuum pump was passed through a separate condenser, and a small additional amount of condensed steam was thus obtained. All temperatures were taken with mercurial thermometers, in mercury cups where necessary. All pressures were taken with mercury gauges. The water levels in the boilers were taken and suitable thermal corrections were made when these were not the same at the end and beginning of each trial. It was noticed that there was a great difference in the gauge glass readings if the steam pressure varied even a little. This was doubtless due to the expansion or contraction of the bubbles of steam attached to the boiler walls, the effect of which was great at such low pressures and where the total heating surface was so large compared with the volume of water. It was also noticed that the vacuum was less when the plant was working below atmospheric pressure. The reason for this was that the boilers were not perfectly air-tight, and air leaking in gave the dry vacuum pump more to do.

Wind Gauge.

All readings were taken every quarter of an hour, except those of the barometer, anemometer, and level of the Nile. The anemometer was fixed in a rough "weather-cock" so as to keep it always normal to the direction from which the wind came. In the case of the engines at Erith, the testing plant was much more complete. For example, convenient and easily changed arrangements were made for testing either engine alone, but using the same condensing plant. Also for running the Low Pressure engine with the exhaust steam from the High Pressure engine: for either engine to drive the auxiliaries, or for these to be driven by an electric motor (with accompanying ammeter and voltmeter), the change being made by a clutch while the plant was running: for measuring the condensed steam from the jackets, and for the determination of the dryness of the steam.

Dryness Fraction.

The arrangements for the latter may be mentioned as they were the same in America, England and Egypt, and were somewhat unusual as the steam "pressure" was frequently below atmospheric pressure, and consequently the steam would not flow through the calorimeter in the usual manner. In all cases a Carpenter separating calorimeter was used, but owing to the lowness of the pressures of course the usual dial readings were useless, in fact the pointer never moved! The sampling pipe was fixed in the steam main in the usual manner. From the discharge end of the calorimeter, a $\frac{1}{4}$in. iron pipe was taken through a small condenser coil and then into a closed steel drum with a

gauge glass. This steel drum was in turn connected to the large condenser of the engine so that it was under a good vacuum. The steel drum was calibrated so that it was known what weight of dry steam was represented by a rise of, say, one inch of the water level in the drum. The moisture in the steam was collected in the calorimeter and read in the usual manner. This quantity divided by the sum of the weights of it and the dry steam gave the wetness fraction, which was thus obtained by absolute measurement, *i.e.*, no reliance was placed on the calibrated nozzle which is so useful under ordinary conditions.

Brake Horse-Power.

The brake horse-power was measured by means of Prony brakes, the ends of the levers resting on Denison platform weighing machines. This arrangement usually causes great oscillation of the graduated arm of the weighing machine, but the difficulty is completely and easily overcome by the author's device of having a dash-pot attached to the end of the graduated arm. The dash-pot is merely an iron plate about 9 in. in diameter in a bucket of water.

Self-Starting.

Two interesting experiments which were made in Egypt may be mentioned. In the ordinary way a small petrol engine was used to pump up the vacuum first thing in the morning in order to start the plant, after which the main engine drove the auxiliaries. It would obviously be convenient if the necessity for such a petrol engine could be done away with, hence an attempt was made on 26th August at 3·24 to start the engine without a vacuum, but with a steam pressure of 9·6 in. Hg. above atmosphere (=4·7 lb. sq. in. by gauge). The suction pipe was previously charged with water, the stroke of the irrigation pump was reduced to zero, and the valves of the engine were moved by hand. After considerable trouble a small vacuum (about 10 in.) was formed by the dry vacuum pump, and the engine speed rose to about 50 or 60 r.p.m. Then an attempt was made to give a stroke to the irrigation pump, but the speed of putting on this stroke was so slow that the condenser got warm, the vacuum fell, and the engine stopped before the pump stroke was even 1 in. long. So there was no circulating water and no real start. The working of the valves by hand (which is not a difficult matter and can be done by one man) would probably not have been necessary had the governor been in order so as to have increased the cut off to say $\frac{3}{4}$ stroke. Also had there been a tankful of cold water from which to supply the condenser by gravitation for say $\frac{1}{4}$ hour, the start would probably have been successful. When another attempt was made, the exhaust valves got hot and the spider which operates them became tight on its cylindrical guide, so the experiment had to be stopped. Sufficient experience was however

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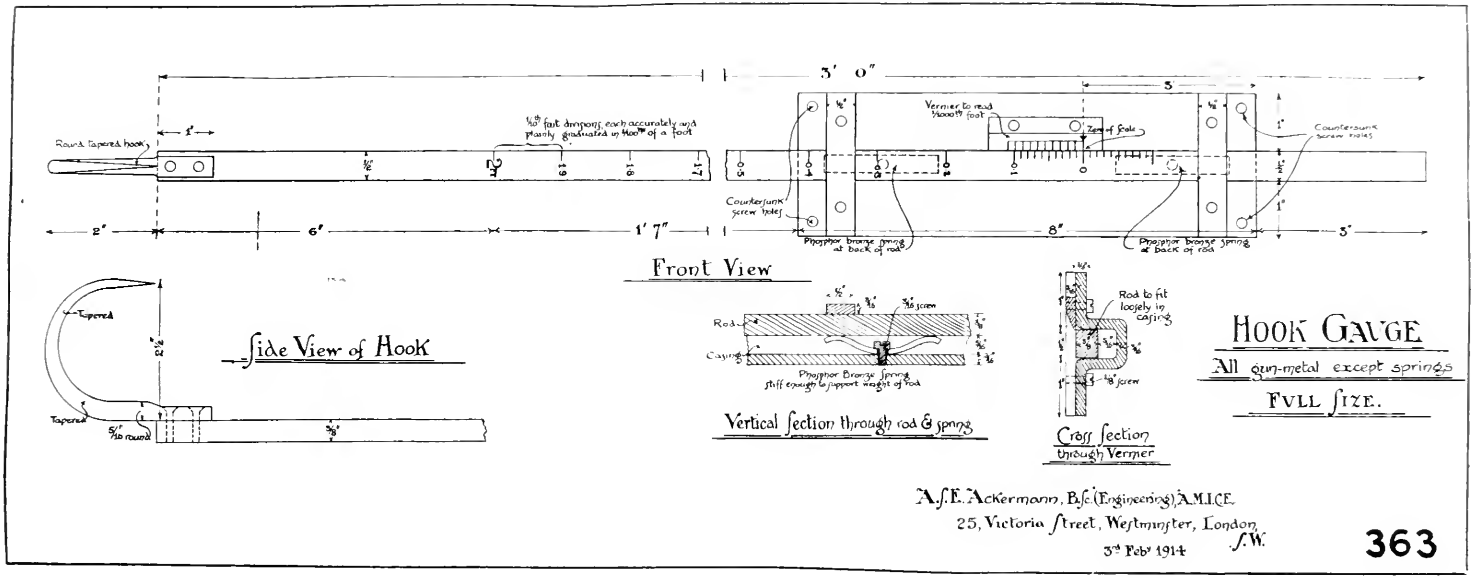


FIG 21.

gained to show that it is very probable the plant could be made to do without the petrol engine.

Returning Mirrors to Morning Position.

Another use for the petrol engine was to rotate the mirrors from their evening to their morning position after the day's work was done. Here, again, it was felt the main engine might very well be made to do this work, so at 4.30 on 27th August we attempted it. The circumstances were favourable for we had just finished a trial with steam at 9·1 ins. Hg. *above* atmospheric pressure, the boilers were well filled with water at the corresponding temperature, and the vacuum was 27 in. The stroke of the irrigation pump was reduced to 2 in. The rotating gear was on top speed. By 4·48 the mirrors were in their "noon" position, *i.e.*, vertical. By 4.50 the vacuum had fallen to 25·5 in. and the steam pressure to 11·2 in. *below* atmospheric pressure. At 5.0 the engine stopped for want of steam. The mirrors were then heeled over about 35° East of vertical. It was obvious that a larger water capacity in the boilers would have enabled the mirrors to have been rotated completely into the morning position.

In conclusion, the author believes this is the first time any reliable and official trials have ever been made of Sun-power plants and that such plants have been fully described, and long as this paper is (it must be remembered it deals with work spread over nearly four years) he is very conscious that many interesting details have been omitted.

In his reply to the discussion, however, he hopes to be able to give further particulars if they are asked for.

Bibliography.

The literature of the subject is very meagre, the following list including probably every complete book relating to the utilization of solar energy as well as those that contain only a chapter or two on the subject, and the principal articles that have appeared in English and American periodicals. The author will be glad to learn of any omissions.

La Chaleur Solaire, by August Mouchot, 1st ed., Paris, 1869 ; 2nd ed., Paris, 1879.

Contributions to the Centennial Exhibition, by John Ericsson. New York, 1876.

Conférence sur l'utilisation direct et industrielle de la Chaleur Solaire, par M. Abel Pifre, ingénieur civil. *Paris Exhibition,* 1878 Conférences, Série I.

Comptes-rendus de l'Académie des Sciences, Paris, T. xci., 1880, p. 368, par M. A. Pifre ; et T. xciv., 1882, pp. 943-4, par M. A. Crova.

Nature, 3rd Jan, 1884.

Utilizing the Sun's Energy, by Prof. R. H. Thurston, Dr. Eng., Smithsonian Rep., 1901.

Radiation in the Solar System, by Prof. J. H. Poynting, F.R.S., Brit. Assoc., 23rd August, 1904.

Solar Heat; Its Practical Applications, by Charles H. Pope. 1st ed., Boston, 1903; 2nd ed., Boston, 1906.

The New Astronomy, by S. P. Langley, 1900.

The Sun, by C. A. Young, 1904.

The Scientific American:—

16th March, 1901.	10th Oct., 1908.
9th May, 1901.	31st Oct., 1908.
26th May, 1906.	31st July, 1909.
21st Sept., 1907.	21st May, 1910.
9th May, 1908.	12th Nov., 1910.

Engineering News:—

9th May, 1901.	13th May, 1909.

Engineering Record, 25th April, 1903.

The Sun, by C. G. Abbot, 1911.

Radiation, by P. Phillips, D.Sc. (c. 1912).

Natural Sources of Energy," by A. H. Gibson, D.Sc., 1913.

The following are eight articles by Mr. C. G. Abbot, Director of the Astrophysical Observatory of the Smithsonian Institution (in some cases he is joint author with others), and published by that Institution:—

The Silver Disc Pyrheliometer, 31st March, 1911.

The Value of the Solar Constant of Radiation, April, 1911.

Do Volcanic Explosions affect our Climate? 1913.

The Radiation of the Sun, 1913.

Smithsonian Pyrheliometry Revised, 1st Feb., 1913.

Measurements of the Solar Radiation, March, 1913.

Report of the Astrophysical Observatory for the year ending 30th June, 1913.

Variation of the Sun, Sept., 1913.

Discussion.

The **President** moved that a vote of thanks be given to the author for his very important paper. Probably when Mr. Ackermann began the paper he did not know the task which lay before him. It was to be regretted that the paper had to be read through so hurriedly, but that was unavoidable on account of its length; however, the members would have an opportunity of reading it in the Transactions. The subject was of great importance, and its novelty gave it an added interest.

The vote of thanks was carried by acclamation.

The following letters were read :—

Mr. Frank Shuman wrote :—" I must compliment you on the masterful manner in which you have brought into order the many new problems involved, and thank you for the valuable assistance you have given us throughout our work. I regret very much that it will be impossible for me to attend the reading of your paper before the Society, as I am called to America at once on important business which cannot possibly be postponed, and must sail on the 3rd April.

" It will interest you to hear that on March 19th, by invitation, I explained for over an hour the practical problems of sun power to the assembled German Reichstag."

Sir Wm. Ramsay, F.R.S., wrote :—" Many thanks for the advance copy of your paper, which I have read with the greatest interest. I must congratulate you on having got so far; keep pegging away and you will come out on top. I am sorry that, as we are in the turmoil of moving house, I shall be unable to hear the paper."

Mr. James Swinburne, F.R.S., wrote :—

" I have read your paper with great interest. Two things strike me : (1) That it is important to use as many reflectors as possible so as to get as large a temperature range as possible ; (2) water is not the right fluid to use. I cannot make out without calculations how far you expand your steam. If the steam is supplied at 212° F. you cannot expand it down to a low temperature without having an enormous engine, so that your temperature range is from 212° F. to the temperature corresponding to the pressure of the steam in the cylinder just before the exhaust is opened. I have no figures for petrol, but alcohol seems more promising than steam, or you might use a double engine with steam and SO_2, an arrangement about which there was some excitement in Germany a few years ago."

Professor C. V. Boys, F.R.S., congratulated Mr. Ackermann on his paper. This was the first full account of sun-power that he had seen, and at a future time, when such machinery was more known and used, it would be the one thing that would be referred to. The parts of the paper which had interested him most were the comparative results obtained when steam was developed at different pressures. He had urged last year as insistently as he could that strictly comparative tests should be made on the same day with identical sections of boiler in the same state of dirtiness or cleanliness, with exactly the same atmosphere and everything the same for both in all respects except that the pressures would be different and that the steam would be condensed in the ordinary way by means of a condenser and the water boiled off so determined. It was only when such tests were made that one could arrive at a conclusion as to what was the best pressure at which to work. He had never believed that the atmospheric pressure, which Mr. Shuman was bound to adopt in his earlier form of boiler in America, would be the most suitable pressure to adopt. Of course it was a problem of maxima and minima, and it was difficult to arrive at a conclusion by any calculation. This could only be got at by experiment, and it was for that reason that he wished the tests to be made. They would see, as Mr. Ackermann had already explained, that, as the pressure of the steam was made gradually more, the temperature was greater and so the rate at which the heat, which was already absorbed, was escaping got greater. It was true that the heat in the steam was greater when the steam was at a greater pressure, according to principles which were perfectly well known, but unfortunately, they got a greater amount of heat in the steam at a still greater expense of sunpower, because of the greater loss of heat from the hotter boiler, and that at once brought them to the question of the coating of the boiler with glass, and the conditions when that coating was useful and when it was not useful. As far as he was able to follow the paper, he did not think that that side of the question had been dealt with as fully as it might have been. Supposing they took one of Mr. Shuman's original boilers with a very large surface in proportion to the area of sunshine which was allowed to fall upon it, then the proportionate loss of heat to the outer side would, of course, be greater. As the concentration of the sunshine was increased the temperature of the boiler did not get any higher ; it remained the same. All that was being done was to produce more steam for every square foot. So the proportionate loss of heat to the outer air would get less and less ; but that, unfortunately, varied much from day to day, and especially was it affected by the wind. The wind was a thing which could not be calculated. With increase of wind

the loss of heat was very seriously increased. One method of reducing that loss to a moderate extent was suggested by Mr. Shuman, and it was he believed tried in Egypt. But, unfortunately, he (the speaker) had not been to Egypt and had not seen it. The method was to put a septum down from the lower edge of the boiler to the bottom of the parabolic mirror. By putting in that septum which did not interfere with the sun's rays the transverse movement of the air was interfered with. It prevented the wind whistling round the boiler as it would do if the septum were not there. With the larger flat boilers which Mr. Shuman had in America he was bound to prevent the large proportion of the escape of heat into the air by coating them with glass, one sheet of glass or two sheets, according to the boilers he was using, making a hot-house frame. That had the great merit that it caused the loss of heat as dependent on the wind to be very much less variable than it was when there was a naked boiler. The wind was nothing like so bad when it blew on the outer glass as when it blew on the boiler. But the application of the glass was not necessarily advantageous, and it was in this connection that one met with a curious result. One did not know always which was the best, for, as the concentration of the sun was increased twice, three times, four times, nine times, or twenty times as the case might be, a glass envelope to the boiler, would reflect always the same proportion of the incident heat, while it would retain only the same amount of heat for a given area of boiler, and the result was that, as the concentration was increased, the loss of heat by reflection went on increasing, whereas the gain in the other respect did not, so that with sufficient concentration glass could become disadvantageous, and when the wind was more a greater concentration was required before glass could be discarded. So it was one of those problems with reference to which it was a little difficult to say, " This particular proportion is always best." It was not: what was generally the best could only be obtained by experience. It was with the view of getting exact figures and the best pressure at which to work that he had been so anxious for tests to be made of the sort which he had just described. He made some calculations a few months ago, but they were based entirely on a sheer assumption of what proportion of heat might be likely to be lost in the air. In a calculation of that sort there was no value whatever. It was merely that he wanted to have some idea. The conclusion which he then came to was that the engine-power value of the steam would be best at about one atmosphere of pressure above the atmosphere, or two atmospheres absolute. Mr. Ackermann showed by means of tests which were not strictly comparative, because they were made on different days, that that

pressure would appear to be too high. Still he (Prof. Boys) thought that, with greater concentration, which he believed would prove to be advantageous, something like two atmospheres would be the better pressure at which to work. Then, at any rate, the trouble of starting the whole machinery with a petrol engine would be avoided. The machine would start itself, and afterwards there was no doubt it would turn the mirrors over into the right position for the next morning's work.

Sir George Denton, on being invited by the President to speak, said that he had not sufficient technical knowledge to deal with the question. He regretted very much that he could not add anything to the discussion except to offer his best thanks to the author.

Mr. Segar Bastard remarked that he had no technical knowledge of the subject, but he had seen the sun-power plant at work at Tacony, and was so satisfied with it that he contributed something financially towards the later experiments that had been made. He was satisfied that the results obtained were such as fully to warrant further experiments.

Mr. C. Liddell Simpson said that he would like the author to add to his paper the name of W. Adams. Mr. Adams was Deputy Registrar of the High Court, Bombay, in 1878; he made some very interesting experiments in connection with the utilisation of solar heat, and he went so far as to get a small pumping plant to work in Bombay. He concentrated his energies more on producing something that could be used for domestic purposes, and made a very interesting octagonal cooker of looking-glass. The author had shown them a photograph of a small Adams cooker which was reproduced last year. This sun cooker had been sent out to Australia for use where there was more sun than in this country. Mr. Adams's paper was very largely noticed at the time, being published in the *Times* and the scientific papers.

He had followed with a great deal of interest the experiments which had been carried out in Egypt, but he thought that Mr. Shuman and Mr. Ackermann would have saved themselves a great deal of time and trouble if they had simply taken a well-designed low-pressure steam cylinder of a horizontal engine, with its cylinder steam-jacketed separately, and had used superheated steam. With such an engine he was perfectly convinced that they would have had as good results as they had obtained with the specially designed engine at Erith.

As regards the experiments made on the pumping plant in Egypt, they were most unsatisfactory. Nothing would convince him that the solar pumping plant was a practical solution

of the utilisation of solar energy unless he saw records of some months' continuous running, day in, day out. Solar heat had been used to work heaters for heating water on the Pacific coast of the U.S.A. for years past. A certain amount might be done with small cooking plants for use in India or in the desert. He thought that, when the author spoke of a pump that had a slip of 35 per cent., it would have been much better not to have started on any trials until the plant was in such a condition as to give proper results. As regards the pumping plant in Egypt, he would undertake to take out an old Cornish engine and get results quite as good as the engineers there had obtained. It was not possible to run a pumping plant economically with an independent condensing plant as was used on some of the American plants described.

What was required was to increase the diameter of the cylinder and drive the pumps direct without belts, etc., running, say, 50 revolutions a minute with the surface condenser placed on the delivery side of the pump fitted with attached air pumps, both surface condenser and air pumps to be large for their work. At many of the old pumping stations, following the traditions handed down from the time of Smeaton and James Watt, one could see the slow-running old-fashioned Cornish pumping engines working with low steam pressures and carrying high vacua, consuming about 30 lb. of steam per pump horse power per hour.

There was another point to which he took very great exception. It was with regard to the pumping plant. Why was it necessary to have a variable stroke on it at all? It was only necessary to alter the revolution of the engine to suit the steam supply. It was not necessary to have a governor on such a plant. The speed of the engine could be controlled by hand.

As regards not being able to start, how was it that in the old days engineers never had auxiliary air pumps or special arrangements to start the old Cornish engine, or the old-fashioned fly-wheel engines? They always did it by admitting auxiliary steam. In this country he had come across examples of the old-fashioned fly-wheel pumping engines with very low-pressure steam, and they were all handled without any auxiliaries at all. The question of the utilisation of the sun's power was a very fascinating one. If it was possible to produce small plants that would run economically and well, there would be a very great field for them in India alone.

The problem of the utilisation of the heat of the sun was a very old one. Many working plants had been tried by a great number of inventors. It was only by the expenditure of time and trouble that Mr. Ackermann had succeeded in collecting so much valuable data into such a concise form. Any engineer

who had the problem of utilisation of solar energy under consideration would find the information which Mr. Ackermann had collected in this paper of the greatest value and assistance.

Lord Headley asked whether the utilisation of solar heat could be placed on a commercial basis, and whether the cost of the plant would not be excessive if designed to produce a very large horse power. The utilisation of the rise and fall of the tides had very often been tried, but it was difficult to construct a plant that was not very costly in proportion to the horse power developed.

Dr. C. V. Drysdale said that almost all sources of power were derived, either at first hand or second hand, from the Sun. In this country sun-power was used mostly in the form of coal, the supply of which was being seriously depleted. All other sources of energy which were being used, whether wind, tide or water power, really came from the Sun, so it was important for engineers to consider how the Sun's immense store of energy might be directly utilised. The author had considered the utilisation of the Sun's energy by mechanical means. Looking at it as a purely scientific problem, that was one of the worst uses which could possibly be made of solar energy. From the nature of things the energy could be obtained only in the form of heat, and it appeared that it could be used only by getting low-pressure steam. He did not see any hint in the paper that the author expected, for some time, at any rate, to get high-pressure steam, and low-pressure steam gave a very poor efficiency.

Another point which, he thought, ought to appeal to all, was the question of food supply, which was largely produced by solar energy. This energy was used in two or three forms: (*a*) directly by the plant and (*b*) to help the combination of substances within the soil or in the air, in order to produce nitrates and other ingredients for the fertilisation of the land. The total amount of fertilising material on the earth's surface was by no means inexhaustible.

In Norway at the present time nitrates were being produced by electrical action, either by the use of an electric arc or by indirect electrical processes. The problem of producing nitrates was a very simple one. All that was necessary was to get the nitrogen and the oxygen of the air to combine; the difficulty was that of producing a high temperature for the purpose. At present the object was being achieved by the electric arc, but the direct concentration of solar energy seemed better from the economic point of view, because it would be obtained directly, instead of through the extremely inefficient process of transforming from mechanical to electrical energy, and then to the arc.

The question was whether it was possible to concentrate the solar radiation sufficiently to make it immediately applicable. He found by calculation that the highest temperature that could be obtained was about 3,500° C. As a matter of fact, the temperature in furnaces which produced the fixed nitrates by electrical means was about 3,500° C. He thought it unlikely that in practice that temperature could be obtained from the solar energy for that would be the maximum due to concentration with perfect mirrors perfectly arranged. It struck him that a combination of the two things, namely, a direct concentration of heat at the focus, combined with a certain amount of heat produced electrically by Mr. Shuman's solar plant might solve the difficulty. One of the simplest processes for producing atmospheric nitrates was with a long arc in a tube through which air was forced. The air was raised to the point of combination and afterwards was rapidly cooled. If that tube were in the focus of one of the mirrors, and was thus raised to a very high temperature, and a small amount of electrical energy was added or an arc formed, it was possible, he thought, that a considerable amount of combined atmospheric nitrogen might be obtained with a very small amount of mechanical energy.

Another serious point as regards agriculture, especially in tropical countries, was the absence of moisture, which, although it might be in the atmosphere, was not precipitated. It was possible to produce precipitation by an electrical discharge, and solar energy might aid in that matter. Taking the case of India alone, his own investigations had led him to believe that seven or eight millions of people died every year from under-nutrition. If the application of means such as he had suggested could do something to solve the problem it would be a great blessing to humanity. He hoped that engineers generally would give the greatest attention to the problem, because, the more one considered it, the more one felt that the problem was one which would be forced upon us. In the utilisation of solar energy was one of the great hopes for the future as regards our sources of power. He did not think that engineers ought to allow any obstacle to get in the way of developing it to the utmost, and considered that Mr. Ackermann's paper would have the most valuable results in indicating the lines along which such development should proceed.

Mr. W. M. Mordey recalled Stephenson's remark that coal was bottled sunshine. Although coal had been seriously worked for only about a century, we were told that the store accumulated during millions of years would be used up within the next hundred years. Therefore, the attempt to use the energy of the sun as it came was of great interest.

The author had not only dealt with the broad question of raising steam by sunshine, but had gone into the details of a special engine for using the low-pressure steam produced. He ventured to think the former was the point of most interest just now. They wanted to know the output in pounds of steam per acre at a stated pressure, and the inclusive cost of it, and for certain purposes it would be of great interest to know the amount of steam at a given pressure that could be got if some storage arrangement were used to equalise the output, for even in countries like Egypt the sun sometimes refused to shine.

Perhaps the author would also compare the cost of power produced by such arrangements with that of power produced by other means. It was unfortunate that so many experiments in connection with the use of power had to be made with the steam engine, which was a very wasteful tool, particularly in small sizes. The late Dr. Diesel, in an address a year or two ago, at the Institution of Mechanical Engineers, made the interesting suggestion that the problem of obtaining power in hot countries might be solved by using the power of the sun to grow oil-producing plants and consuming the oil in oil engines. That seemed quite a practical suggestion, and the oil engine had the great advantage that the efficiency in small sizes was high.

He felt that the author and those associated with him had done a very useful and practical piece of work for which they deserved the thanks of all engineers, and he hoped that satisfactory results would accrue from their public-spirited labours.

Mr. G. Hally said that perhaps he might be allowed to give figures which would show how the cost of the sun-power plant compared with the cost of coal plant. The success of a sun-power plant naturally depended upon the cost at which it developed its power. A 50 horse-power sun steam-generator manufactured under proper conditions and erected in Cairo would cost £1,560. Further up the country the cost might be greater in consequence of the additional transport ; but, on the other hand, the additional cost would be nullified by the fact that the generator would give more power. A coal-fired steam-generating plant of equal power, including boilers, superheater, economiser, feed pump, boiler-house, chimney stack, and coal store would cost, erected in Cairo, £770. The cost of the engines and pumps would be practically the same in the two plants, so that it might be eliminated in the comparison, but, approximately, the steam-raising part of a sun-plant cost twice as much as the equivalent of the coal-plant. The total cost of a complete sun-plant, including the engine and pump, would be about 50 per cent. greater than the cost of a complete coal-plant.

A statement had appeared in several daily and technical papers to the effect that the Meadi plant had cost £30,000, but this was so obviously ridiculous that it hardly required contradiction.

As regarded the running powers of the plant, the true comparison between engineering plants was not their capital cost but their annual charges. Suppose that the cost of a 50 horse-power plant was £1,560, the interest on the capital at 5 per cent. and depreciation and wear and tear at 5 per cent. would come to £156 per annum. If they took the coal plant as costing £770, the corresponding items at the same rates totalled to £77 per annum, a little less than half. But if the coal plant used only 2 lb. of coal per brake horse power per hour it must get its coal at 9s. 8d. per ton delivered to the furnace doors to equal the sun-plant when working 3,650 hours per annum. As coal in the tropics cost about £3 per ton, the coal bill of the coal-fired plant, together with the other charges, totalled £566 per annum, showing a saving for the sun-plant of £410 per annum, nearly 52 per cent. of the extra cost, £790, so that in less than two years the sun-plant would have paid its extra cost, and in four years its total capital cost.

With regard to the regularity of the running of sun-power plant and the request of one of the speakers for figures of a series of tests, no doubt it would be very desirable to have such figures, and certainly there would be an endeavour to get them at the earliest possible moment, but it must be remembered that, immediately after the tests referred to in the paper were made, Mr. Ackermann and his assistant came home. There were records in the office of the Sun Power Co. of the plant since that time, and probably they would be published.

Mr. J. S. Wilson congratulated Mr. Ackermann, not only on the very valuable set of results and the accumulation of facts relating to the development of sun-power contained in the paper, but on having published the details of the tests carried out by him, in spite of the fact that some want of adjustment of the pumping plant had rather marred the over-all results. Two points had particularly interested him, and he hoped Mr. Ackermann could give some additional explanation. The first was the great effect of the *humidity* in the atmosphere upon the working of the absorbers. The other point related to the reduction of efficiency by *wind*. Some work done by Professor Morris had a bearing on these effects. Professor Morris had elaborated a very ingenious method of measuring wind velocity (*Engineering*, September 20th, December 27th, 1912). The method consisted of heating a fine platinum wire by an electric current. The wind flowing past the wire carried away the heat, and the wind velocity

was measured by the change in the resistance of the wire due to the cooling effects of the wind, or alternatively by measuring the potential necessary to keep a constant current passing through the wire. Wind probably produced a considerable effect on the efficiency of the absorbers, just as it affected the platinum wire. Regarding moisture, however, Professor Morris found that dampness of the wind had little or no effect on his measurements. It appeared somewhat extraordinary, therefore, that moisture should have the great effect on the efficiency of the absorbers indicated by the figures given by Mr. Ackermann. In looking through the table of results given by the author he was astonished to find that no trials of the plant had been made before 10.15 a.m., although the plant had been kept working till 4.25 p.m. His knowledge of Mr. Ackermann's activities led him to believe that he must have had some very good reasons for omitting to utilise the early hours, during which the sun must have shone fairly strongly in Egypt.

Mr. C. T. A. Hanssen said that the subject was evidently still in its infancy, and from the information which he had gathered casually from the reading of the paper he thought that many improvements could be suggested.

One thing that struck him was that glass mirrors were not the proper things for the reflectors, the reflecting surface being at the back of the glass. Experiments on electric light showed that plain transparent glass absorbed as much as 12 per cent. of the light that passed through it, so that when light went through glass and was reflected from the surface at the back, as much as 24 per cent. of the light might be absorbed by the glass. Therefore, he thought that metallic reflectors would be better, and they would also be cheaper. There were metals which were cheap and would not tarnish in the air, and he believed that they could be used to much better purpose than glass.

Anther point was that a great deal of heat must be lost in consequence of its passing through at the back of the mirrors. That seemed to be proved by the fact that much better results were obtained when the ground beneath the mirrors was heated. They would get a better result by packing the space between the mirror and the back of the frame with non-conducting material that would not perish, such as silicate cotton, so as to prevent any of the heat passing away behind the mirror, and so that all the heat might be concentrated and reflected.

It had been stated that in the glass surface round the boiler there was another source of loss. There was a loss of 12 per cent. of the light in its passing through the glass. As Professor Boys had already pointed out, there was an open space from end to

end for the air currents and wind to get at the boiler. If the open parabolic trough were subdivided and no air inlet openings were left at the bottom of it, one could just as well keep the heat inside the parabolic mirror by means of the subdivisions as by means of the glass frame. All the glass and ironwork round about the boiler really took away the sunlight. Therefore the boiler ought to be completely naked, but as much as possible protected from the air currents by cross walls. The engine was defective, and probably, as Mr. Simpson had said, a Cornish engine would have given better results than the very good Shuman low-pressure engine that Mr. Ackermann had tested at Erith.

It had been suggested that sun-power should be used for producing nitrates. He had taken a great deal of interest in nitrates, but he thought that sun-power would be completely "out of the running" in producing nitrates. Water power, working day and night, twenty-four hours, all the year round without stopping, could produce 1 horse-power for a year for about 25s. At that rate it would only just pay to make nitrates at such a price that the cost of the nitrates was lower than the cost of the corn which could be produced by using them. He did not think that the sun-power engines could possibly produce power at anything like 25s. per horse-power per year running continually day and night. and therefore he thought that for that purpose sun-power was entirely out of the running. But for places where water was available for irrigation and where it had to be raised by pumping, the sun-power must be invaluable, and must greatly increase the quantity of food produced in the world for the use of its inhabitants.

Mr. Bonacina congratulated the author very heartily upon the results of the pioneer work which he had done. The perfecting of sun-power plant would transform the desert areas situated on each side of the equator in about latitude 30 deg. N. and S. into populated areas. He should like to ask whether any suggestion had been made for applying solar radiation to the working of railways. It seemed to him to be a matter not so much of the concentration of heat by suitable reflectors as the successful application of the heat to the boilers. If there was a climate in which such a thing would be possible it was that of Egypt, where sunshine might generally be relied upon during the greater part of the day.

With regard to the precipitation of moisture by electrical means, he thought that meteorologists were generally agreed that no great amount of moisture was capable of being precipitated by that means. If the general meteorological conditions had a rainy tendency an application of electricity might send down a

few drops over a small area, but the process could never be worked on a large scale.

Mr. F. H. Johnson said that Mr. Ackermann and Mr. Shuman were utilising solar energy which was otherwise being wasted, which cost nothing, and which would not cost anything in the future. Coal and oil were limited sources of energy ; the supply of solar energy was practically inexhaustible.

The author had shown a map of the world with very large areas marked on it where solar energy might be utilised, but one point seemed to have been overlooked—that for all steam engines using low pressure steam, condensers were absolutely essential, and that for condensers water was necessary. The plant had been set up on the banks of the Nile, where large quantities of water were available, but he did not see any chance of getting water in the Sahara except by wells. It was essential that the water supply should be ample in order to obtain a good efficiency. Again, if a Shuman engine were set up in the middle of the Sahara it would be very costly and difficult to transmit the power obtained to any considerable distance.

The question of superheated steam seemed to be important, as much greater efficiency was obtained with superheated steam. In the desert there was every facility for superheating the steam. With the superheated steam one might almost dispense with the steam jacket, and it seemed unnecessary to steam-jacket the engine when one might easily sun-jacket it by using suitable mirrors.

As regards pumps, the method described was complicated, and he thought that centrifugal pumps driven by exhaust steam turbines would be better from a mechanical point of view. It seemed to him to be a matter of having a succession of pumps. By means of tanks it would be easy to equalise the work over the day.

Reply.

Mr. A. S. E. Ackermann, in replying to the discussion, thanked Prof. Boys for his congratulations, which he much appreciated. With regard to the effect of steam pressure on the power value of the steam produced, he thought the experiments showed this fairly well considering the nature of the experiments and the scale on which they were carried out. It was very difficult (especially where the atmosphere was concerned) to keep everything constant except the one factor which was to be the variable. As soon as one tried to do this, the factors which were to be kept constant seemed to get jealous of the factor having the privilege of variability and they all wanted to be variables ! But there was no strict need for the variable pressure experiments

to be made on the same day, provided that the conditions were constant, and it would be seen that on the *one* day (27th Aug., 1913. Table facing p. 106) when experiments at two pressures were made the humidity was no more constant than when different days are considered. Prof. Boys' suggestion of having concurrent experiments with different sections of the absorber was ideal, and would have been carried out, but there were no means of doing this. It would have meant more than duplicating the measuring apparatus and the number of assistants. He would be greatly obliged to Mr. Liddell Simpson if he would refer him to the results of any Cornish engine which were better than those obtained with the Shuman low-pressure engine. A consumption of 22.1 lb. of steam at 16.2 lb. sq. in. abs. per brake horse power hour had never to his knowledge been beaten, and as to using " a well-designed low-pressure cylinder of a horizontal engine," instead of a Shuman low-pressure engine (which really complied with Mr. Simpson's suggestion), on p. 130 would be found the results of Professor Carpenter's test of such a low-pressure cylinder showing that its performance was considerably inferior to that of the Shuman engine in spite of the latter being only $\frac{1}{7}$ the size.

Since the meeting Mr. Liddell Simpson had referred the author to the Proceedings of the I.C.E. for 1882, Paper No. 1,872, in which are given the results of a test by Mr. J. G. Mair (then of James Simpson & Co., Ltd.) of a Cornish engine which is stated to have been one of the best of its kind. The following is a comparison of the results obtained with the two engines :—

	Cornish Engine.	Shuman Low-pressure Engine.
I.H.P.	146	—
B.H.P.	—	94.5
Cylinder	68 × 96in.	36 × 36in.
Thermal efficiency relative to that of a Carnot engine	35.4%	about 53.5%
Steam pressure in lb. sq.in. abs.	46.4	16.2
Steam consumption in lb. per hour	24.15 per I.H.P.	22.1 per B.H.P.

With regard to running day in and day out, he had anticipated that it might be claimed that the tests had been made on selected days, and consequently arranged with the directors before he went to Egypt that he should make trials on six consecutive days. Troubles with the engine-end of the plant and considerations of expense had prevented that, but the next best thing had been done. That is, a complete set of the necessary meteorological

observations had been taken throughout the whole of the two months he was in Egypt. These were given on pp. 121 and 122, and it would be seen that the meteorological conditions on the days on which trials were made were average ones. The trials were made simply when the plant happened to be in the desired experimental condition and when the aforesaid engine troubles would allow them to be run.

The condensing plant was not run independently. It was chain-driven by the main engine, but there was a clutch whereby the drive could be changed to a small petrol engine to pump up a vacuum first thing in the morning. It was explained on pp. 146 and 147 how the use of this petrol engine could be avoided.

It might be possible to work with a pump having a fixed stroke, especially as the output of steam had proved so much more uniform than was expected; but, on the other hand, a fixed stroke might not permit of the necessary range for self-starting, and this latter was the more important point.

Dr. C. V. Drysdale was under the impression that they did not expect to get high-pressure steam. There was little difficulty in obtaining high-pressure steam, but in the earlier stages of Shuman's work it was argued that high-pressure steam was undesirable as it meant a high temperature and a consequently larger loss by conduction and radiation. The Meadi experiments indicated that higher pressures could be used (Conclusion No. 8, p. 114) especially if the concentration was increased and the area of the boiler was reduced, as it was proposed should be done in the next absorber.

With regard to the output of steam per acre, Mr. W. M. Mordey would see it recorded on p. 107 that 0.88 of an acre was occupied by the Meadi absorber. The best output on the 22nd August, 1913, was 55.5 B.H.P., equal to 63 B.H.P. per acre. The *average* power for the 5 hours' run on that day was 59.4 B.H.P. per acre, and the minimum on the same day was 52.4, or a total decrease of only 16.8 per cent.

With regard to growing oil-producing plants and using the resulting oil in oil engines, he had no data, but in Dr. Gibson's *Natural Sources of Energy* it was stated that if timber was grown on land it was possible to obtain only the equivalent of 1 ton of coal per acre per annum, showing that timber production was absolutely out of the question from a power point of view, and it would be seen from the above figures that the Shuman plant was vastly superior.

Coal had been called "bottled sunshine," but it appeared to have been bottled with a very leaky cork, for only about 2 per cent of the original energy of the Sun was stored in coal. In considering this bottled sunshine it was an interesting point to realise that when an ordinary boiler and steam engine were being run, the

energy that was being utilised had been stored for millions of years, whereas in the case of a sun-power plant the solar energy was converted into mechanical power in a few minutes or, perhaps, a few seconds.

Mr. Mordey had also referred to storage of the output of energy by the plant in order to equalise that output. In the figures just given it was shown that the output was wonderfully constant, and for irrigation purposes storage was quite unnecessary, though it could be done at an additional cost.

It was not the Meadi plant, but the whole of the plant and experiments referred to in the paper, which had cost about £30,000.

Mr. J. S. Wilson inquired about the effect of wind. Nobody regretted more than he that he was not able to make many more experiments, but from those which had been made it was not possible to determine the effect of wind, the speed of which had not varied more than from five to ten miles an hour, and it was ten miles an hour only for one day on which trials were made. It seemed obvious that wind must increase the losses by conduction.

It had long been known that atmospheric humidity stopped solar radiation from reaching the Earth, but he believed he was the first to determine the quantitative effect of humidity on the production of steam by solar radiation. He did not think the effects of humidity in the cases of a sun-power plant and Professor Morris's very ingenious hot-wire anemometer were analogous. In the case of the former the moisture in the air got in the way of the solar radiation and stopped some of it. In the latter Professor Morris had shown that the cooling effect by conduction of moist air was practically the same as of dry air.

With regard to not starting before 10.15 a.m. and finishing as early as 4.25 p.m., it was a long story. The boilers were originally of zinc. The consulting engineers had condemned them, but the advice of engineers was not always acted upon, and the zinc boilers perished in a very short time. Consequently the crescent frames of the reflector were designed for holding up only the weight of the zinc boilers, but the zinc boilers were replaced by cast iron ones weighing many times as much as the zinc boilers, and the wonder was that the supporting frames had stood the great extra weight at all. They did so very well when the frames were in about the noon position, but when heeled over to the morning and evening positions the tie members of the bracing showed that the frames were obviously in a dangerous state. Hence a limit was set beyond which they dared not go.

It had been pointed out by Mr. Hanssen that much *light* was lost in consequence of reflecting it by silvered glass mirrors.

Even more *heat* was lost by such reflection. Aluminium reflectors might do, as that metal was fairly cheap and did not tarnish, but it was soft and the surface would soon become scratched by cleaning.

He (the author) did not think it would prove satisfactory to divide up the reflectors in the manner Mr. Hanssen suggested, for the joints of the mirrors were very far from air tight, so the hot air would get out between them, and the temperature of the boilers was comparatively so high that convection currents would be set up regardless of any wind. Thus the losses by conduction would be great.

Mr. Hanssen appeared to have misunderstood him with regard to the heating up of the frames, sand and other surroundings. This heating was by the direct action of the sunlight and by the hot air, and was certainly not due to any material extent to heat passing right through the mirrors. Thermometers were put at the backs of the mirrors, and it was found that very little heat got through, although in some cases the mirrors were poorly silvered.

In answer to Mr. F. H. Johnson, he had been told by several engineers in Egypt that water was frequently found in the deserts, at places 200 or 300 miles from the Nile, at depths of only 30 ft. to 50 ft. below ground level. Hence all that had to be done was to put down a sun-power plant, and water could be obtained and irrigation started. That would mean the starting of a civilization similar to that in Egypt, for without the Nile there would be no Egypt. Egypt without water would be as barren as the Sahara, but by the installation of sun-power plants in the Sahara, conditions could be created similar to those in Egypt, where they obtained no fewer than four crops per annum, one of which was the very valuable cotton crop.

The question of transmission of power scarcely comes in where the solar energy was used for irrigation, but in other cases the difficulties of transmitting sun-produced power would be no greater and no less than those of transmitting energy obtained by any other means. In Egypt civilization had followed the water (the Nile), consequently it did not need much imagination to conclude that if the arid areas adjoining the fertile ones along the Nile were irrigated by means of sun-power or otherwise, those areas too would become fertile and inhabited.

It had been suggested by Mr. Johnson that exhaust steam turbines were more efficient than the Shuman low-pressure engines. He obviously had not read all the paper, or he would have seen on pp. 139 to 141 that the Shuman 30 H.P. engine easily beat exhaust steam turbines even of 300, 1,000 and 1,078 B.H.P.

Note on the Equation of Bouguer and Lambert.

As Mr. W. M. Madden, in his editorial article on "Solar Heat Engines," in the *Contract Journal* of April 15th, 1914, p. 884, referred to Bouguer's equation, the author has added this note to his reply.

The equation is $E = E_0 a^t$, and is explained on p. 83, t being the thickness of the medium traversed. On making a diagram of the Earth, the atmosphere (taken as 100 miles thick) and the Sun's rays to a fairly large scale, the values of t for different zenith distances, z, can be read off pretty accurately. If this is done, the values of E calculated by the formula agree better with experimental results. However, Bouguer did not leave the equation in the form just given, but wrote sec. z for t, the equation then becomes $E = E_0 a^{\sec. z.}$, and it is this form of it which was used to plot curve No. 2 on p. 84. It will be seen that this curve differs materially from the experimental results (curve No. 3) for values of z between, say, 65° and 85°. Again making use of the diagram of the Earth and atmosphere, we see that for values of z from 0° to 60°, the values of t approximate closely to sec. z, but when $z = 80°$ while sec. $z = 5 \cdot 759$ the value of t is only $4 \cdot 430$ (the unit being 100 miles). Hence by then writing $t =$ sec. z we introduce an error of $+\dfrac{5 \cdot 759 - 4 \cdot 430}{4 \cdot 430} = +30\%$, *i.e.*, the value taken t is 30% larger than it should be. The result is that, instead of obtaining $E = E_0 a^{4 \cdot 430} = 0 \cdot 398$ calories per sq. cm. per min. from the equation, we obtain $E = E_0 a^{5 \cdot 759} = 0 \cdot 247$ calories per sq. cm. per min., thus introducing a known error in the final result of the equation of $-\dfrac{0 \cdot 398 - 0 \cdot 247}{0 \cdot 247} = -61 \cdot 2\%$. On calculating the corresponding error between the experimental result and that given by $E = E_0 a^{\sec. z.}$ (curves Nos. 3 and 2 on p. 84) we find that it is $-96 \cdot 6\%$, showing that $\left(\dfrac{61 \cdot 2}{96 \cdot 6} \times 100\right)$ 63% of the total error of the equation $E = E_0 a^{\sec. z.}$ is due to writing sec. z in place of t when $z = 80°$.

May 11*th*, 1914.

H. C. H. SHENTON, PRESIDENT,

IN THE CHAIR.

NOTES ON THE WATER SUPPLY OF GREATER NEW YORK.*

By WILLIAM T. TAYLOR, M.I.E.E., A.M.I.Mech.E., M.Inst.Mun.E., F.R.G.S., Fellow Am.I.E.E., M.Am.S.M.E.

THE total estimated cost of the Panama Canal is £75,000,000, as compared with the estimated cost of the world's greatest water supply system, the creation of the Catskill aqueduct and the Ashokan reservoir, for the city of New York, which is £35,000,000. However, as an exploit of purely technical engineering, the creation of the Catskill aqueduct and the Ashokan reservoir exceeds that of the Panama Canal. Apart from the unique methods of handling materials on the Panama Canal, it may be roughly stated that the problem meant merely digging out earth and rock on a large scale and dredging channels ; to build the aqueduct meant piercing mountains and undermining rivers, traversing deep, broad valleys, and tunnelling through the bowels of the city of New York from end to end 200ft. to 750ft. below the city streets.

In a few months the first link of the world's greatest water system will be completed.† One hundred and twenty-seven miles away the water will begin its three days' journey to the southernmost end of the metropolis from Ashokan reservoir in the Catskill Mountains, and running through a giant aqueduct, pass down the westerly side of the Hudson River, cross under through a huge, deep syphon at Storm King, thence to the Croton reservoir system, and through the present distribution pipes to New York. The aqueduct has an easy flow of 500,000,000 gallons‡ a day. Present natural pressure carries the city water only to the sixth story, but the new scheme, will force water under natural pressure to the eighteenth story of

*The author made several inspection trips over the most important parts of the scheme, with engineers of the works and also with excursionists from engineering societies.

†Mayor Mitchel, of New York, blew up the last ledge with the blast that will mark the official opening of the great underground passageway—this occurred Saturday morning, January 10th, 1914. This final shot—439ft. below the street surface—opened the greatest tunnel in the world.

‡U.S. gallons are referred to throughout the paper. To obtain British Imperial Gallons multiply the figures given by 0·834.

New York's skyscrapers, 295ft. above tide water. The number of labourers employed on the whole undertaking was 17,240; they have been working slightly over seven years, and they are expected to finish the undertaking in 1915.

It has been estimated that the population of Greater New York will be 7,000,000 by the year 1930. To supply such a community with 100 gallons per capita per day would require 700,000,000 gallons, and to meet an average demand for 150 gallons would require 1,050,000,000 gallons per day. New York at present obtains practically all its water from the Croton and Bronx watersheds in Westchester, Putnam and Dutchess counties, and the Ridgewood watershed in Nassau county. Each of these watersheds has already been developed to practically the economic limit, and with the city's growth the draught on them has come to be an excess of their safe yield during a period of dry years. On account of the already high development of these catchment areas very little more water could be obtained from them by the construction of additional works. Greater New York's total average daily consumption of water is at present over 500,000,000 gallons from all sources. Its population is 5,373,000, exclusive of the hundreds of thousands of "commuters" (season ticket holders) and other "transients."

To keep pace with its growth of approximately 135,000 persons per year it was long ago recognised that additions to the city's water supply system would be inevitable. On October 9th, 1905, the Board of Water Supply submitted for approval to the Board of Estimate and Apportionment a plan for obtaining from the Esopus, Rondout, Schoharie and Catskill creeks a supply of not less than 500,000,000 gallons of water daily, at an estimated cost of £35,000,000. On October 27th, 1905, this plan was unanimously approved by the Board of Estimate and Apportionment, and on November 3rd of that year application was made to the State Water Supply Commission for its approval, as provided by law. On May 14th, 1906, this approval was granted, and in less than six months the first construction contract, for 11 miles of aqueduct, was let.

Catskill Water System.

There are four drainage areas from which the supply under development is to be drawn. These watersheds are situated west of the Hudson River in the Catskill Mountains, and lie between lines 75 and 135 miles from New York's city hall. This region is practically unsettled. In the aggregate these watersheds have an area of nearly 900 square miles, and individually as follows: Esopus, 255 square miles; Schoharie, 228 square miles; Rondout 131 square miles; Catskill creek, 163 square

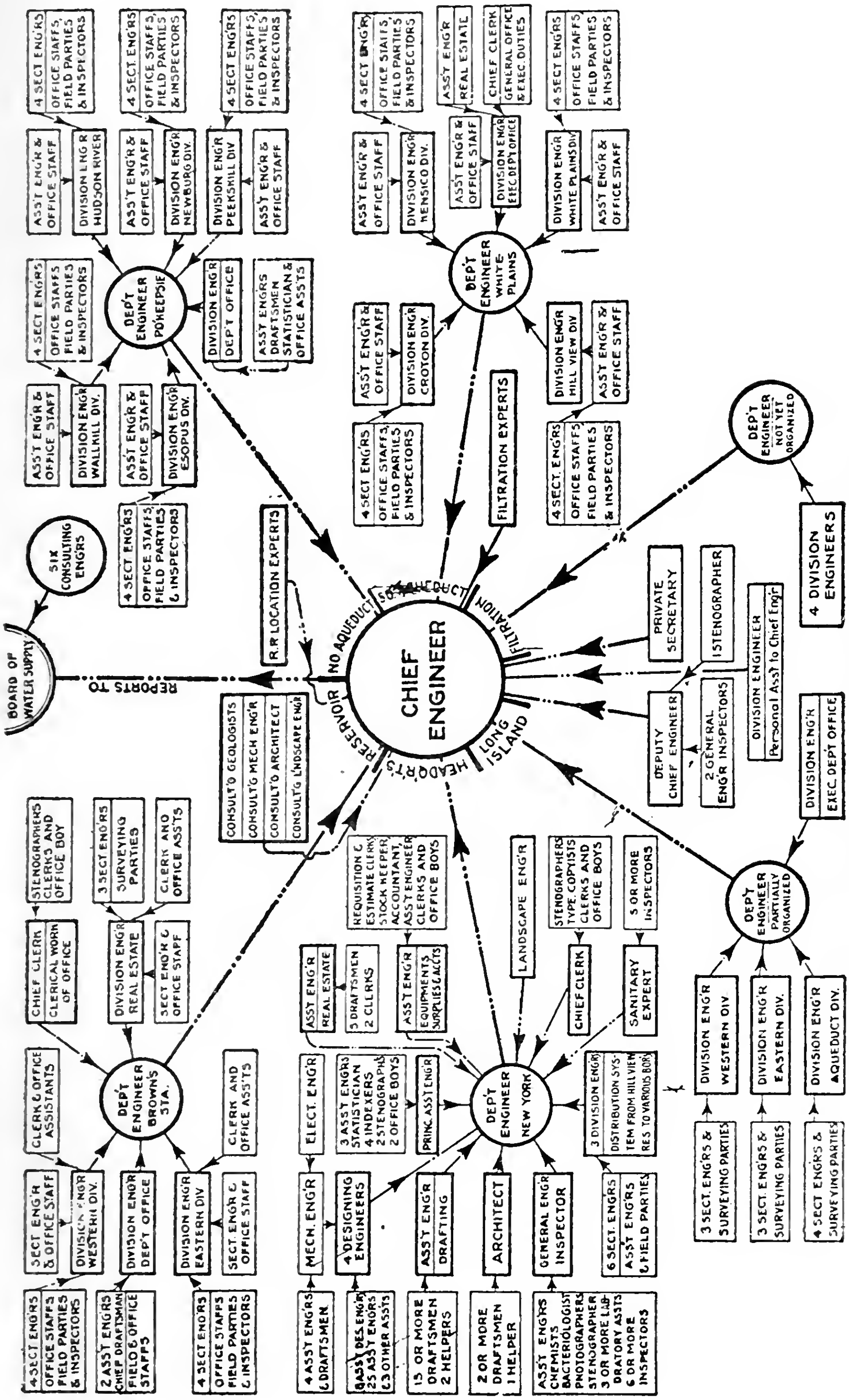


Fig. 1.—Engineering Bureau Organisation.

miles; to which can be added several small contiguous areas, helping to make up the grand total. From this it is estimated that even in a series of dry years 770,000,000 gallons daily can unfailingly be drawn the year round. To collect these waters for the city's use several large impounding reservoirs are to be created from time to time, as found necessary, and interconnected by aqueducts. Only the Esopus watershed is being developed now, but its only reservoir, known by the Indian name of Ashokan, is to be by far the largest and most important of them all. From this reservoir the Catskill aqueduct will convey the water into all the five boroughs of the city. Although in a series of dry years the Esopus watershed cannot be depended upon to supply more than 200,000,000 gallons each day, the Catskill aqueduct is, for economic reasons, being constructed of 500,000,000 gallons daily capacity.

Developments have been in progress for seven years, and the aqueduct is now nearly completed to some of the boroughs. From the Ashokan reservoir, situated in the foothills of the Catskill Mountains, it is almost a three-days' journey for the water to the borough of Richmond, which is on Staten Island, surrounded by the sea, at the southerly entrance of New York bay. In traversing this distance of 127 miles the Catskill aqueduct skirts along many a steep hillside, pierces mountains, descends between rivers and wide, deep valleys, and crosses the Narrows of New York Harbour. From Ashokan reservoir to the city's northern boundary there are 92 miles of aqueduct, and between that reservoir and Croton Lake, the principal basin on the Croton watershed, there are 64 miles. All the engineering, legal and other difficulties and problems have been met and overcome.

The principal quantities of work and materials involved in the Catskill system, as planned for the first development from the Ashokan reservoir to Hill View, are approximately as follows:

	Cub. yds.
Cyclopean masonry in dams	1,425,000
Other masonry in dams and gate-houses ..	425,000
Concrete in core walls of earthen dams ..	325,000
Concrete masonry in cut-and-cover aqueduct	1,525,000
Concrete masonry in grade tunnels ..	250,000
Concrete masonry in pressure tunnels and shafts	480,000
Total masonry (cub. yds.) ..	4,430,000

Excavation of earth for dams	.. ..	6,670,000
Excavation of rock for dams	.. ..	820,000
Excavation for open cut aqueduct	..	7,665,000
Excavation for grade tunnels	.. ..	835,000
Excavation for pressure tunnels	.. ..	1,180,000
Total excavation (cub. yds.)	..	17,170,000

Embankment (rolled) for dams	.. ..	8,080,000
Embankment (other) for dams	.. ..	4,335,000
Embankment (aqueduct) for dams	..	6,010,000
Total embankment (cub. yds.)		18,425,000

Steel pipe and other metals	.. ..	21,250 tons
Portland cement	.. .. ..	5,450,000 barrels

Very good progress has been maintained on practically all contracts, and what are believed to be three interesting monthly peaks of work are :—

Hard rock tunnelling in one heading, 488·5ft. per month.
Shaft sinking in one shift, 138 ft. per month.
Masonry placed in dam, 35,260 cubic yards per month.

For the construction of the main dams of the Ashokan reservoir the following are the quantities as given in the engineers' approximate estimate :—

Earth excavation, 2,055,000 cub. yds.
Rock excavation, 425,000 cub. yds.
Embankment and refilling, 7,200,000 cub. yds.
Portland cement, 1,100,000 barrels.
Masonry, all classes, 874,000 cub. yds.
Rubble paving and riprap, 105,000 cub. yds.

For the construction of the Hill View reservoir the principal items of work include the following :—

Excavation, 3,200,000 cub. yds.
Embankment, 2,800,000 cub. yds.
Concrete in walls and lining, 130,000 cub. yds.
Concrete masonry in tunnels and shafts, 14,400 cub. yds.
Portland cement, 215,000 barrels.

The Board of Water Supply consists of three commissioners, who were appointed by the Mayor of New York. Its forces are divided into Administration, Real Estate, Police and En

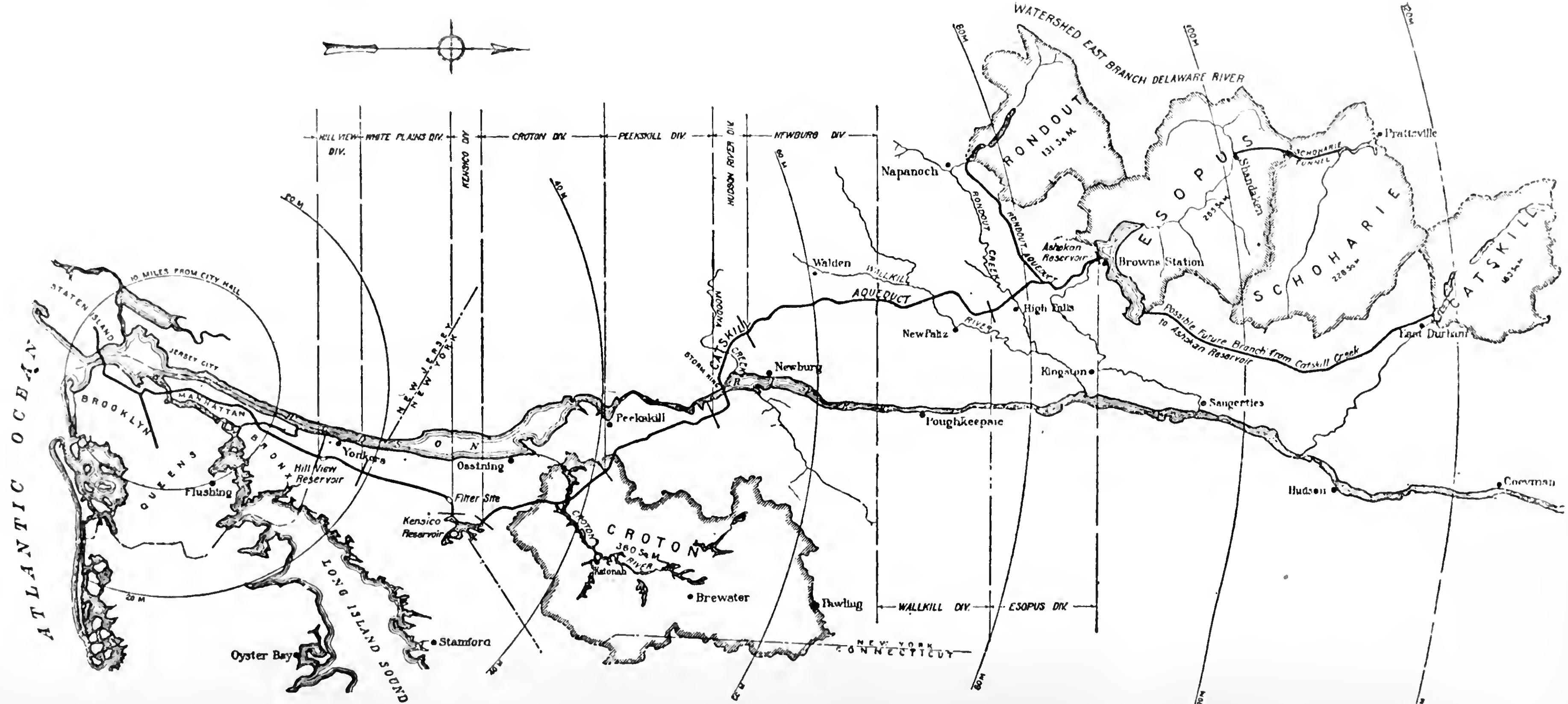


Fig. 2.—Catskill Watershed and Aqueduct.

gineering Bureaux. In the former are the secretary, the auditor, the chief clerk (in charge of pay-rolls, emergency expense accounts and purchasing of supplies) the examiner of real estate and damages, a real estate claim officer, the adjuster of taxes and assessments, and the superintendent of the aqueduct patrolmen. The engineering bureau is composed of five departments, namely, headquarters, reservoir, northern aqueduct, southern aqueduct, and city aqueduct (see Fig. 1).

During the past five years of active construction operation the contractors' forces have ranged from a minimum of 500 to a maximum of 17,240, counting only men actually and directly at work for the contractors. To these must be added men engaged upon incidental work, the men in camp, but for one reason or another idle on any given day, and the large number of men in cement, metal and other manufacturing establishments, widely scattered over the country, engaged on the production of materials, equipment and supplies for the work. It is safe to say that, in addition to the above number of men, thousands of persons have been indirectly employed upon this great undertaking of the city of New York, aggregating a maximum total of about 25,000 men.

The Ashokan Reservoir.

This is situated about 14 miles west of the Hudson, at Kingston, and is being built under contracts amounting, together with the expense for relocating highways and the Ulster and Delaware Railroad, to nearly £3,600,000. The Olive Bridge Dam across Esopus Creek, the Beaver Hill and Hurley Dykes across smaller streams and gaps between the hills forming the natural walls of the reservoir, the dividing wall and weir dividing the reservoir into two basins, and the waste weir over which the surplus flood waters may safely be discharged, are the principal structures of the reservoir. Up to the end of 1912 fully 73 per cent. of the work on these structures was completed.

The general statistics of the Ashokan dam are :—

Capacity, total, 132,000,000,000 gallons.
Capacity, available, 128,000,000,000 gallons.
Water surface, 12·8 sq. miles, or 8,180 acres.
Land acquired, 15,222 acres.
Elevation of water (full reservoir), above tide, 590ft.
Elevation of top of dam, above tide, 610ft.
Length of reservoir, 12 miles.
Length of shore-line, 40 miles.
Length of dam and dykes, 5·5 miles.

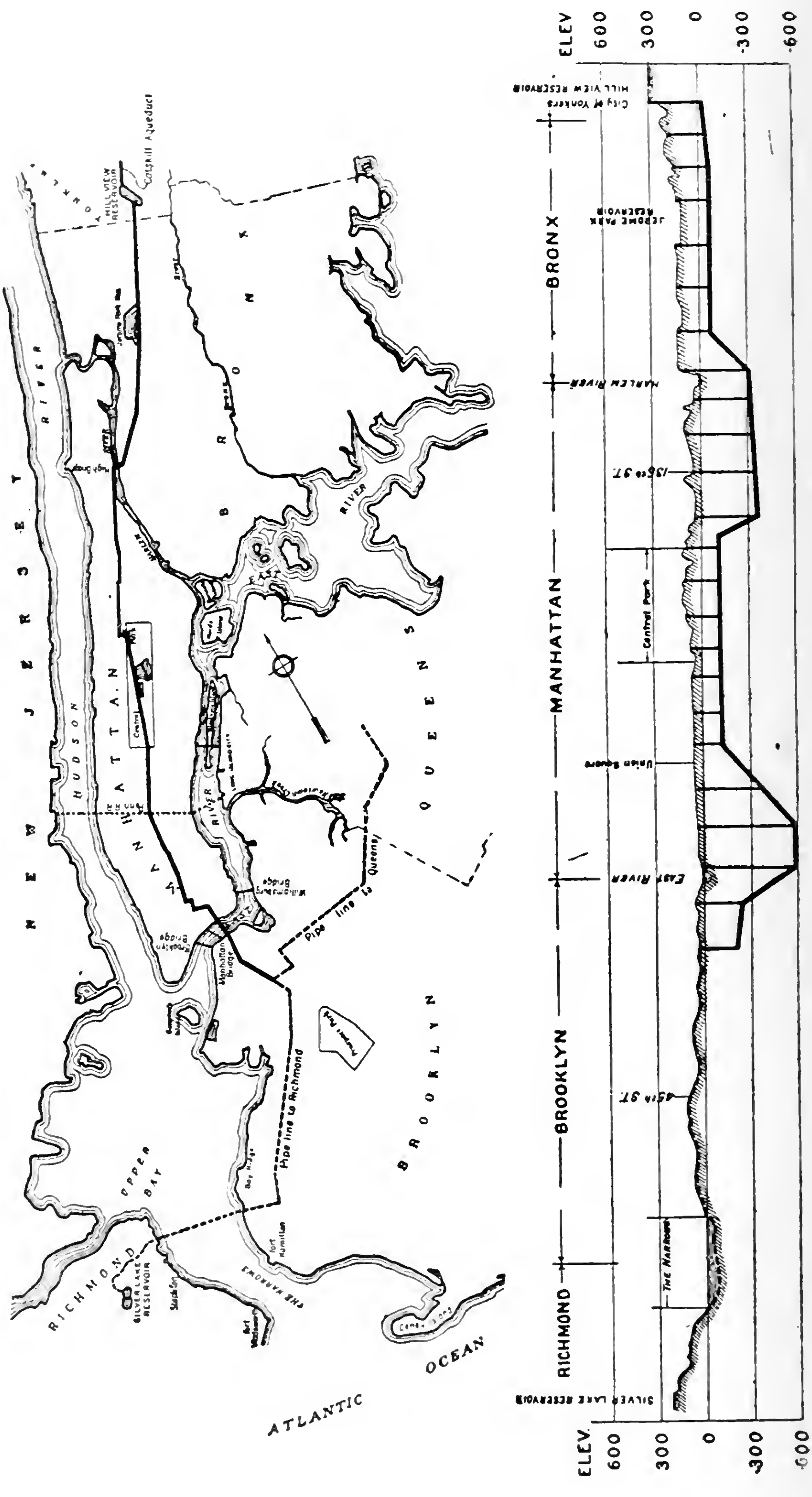


Fig. 3.—New York Aqueduct, South of Hill View.

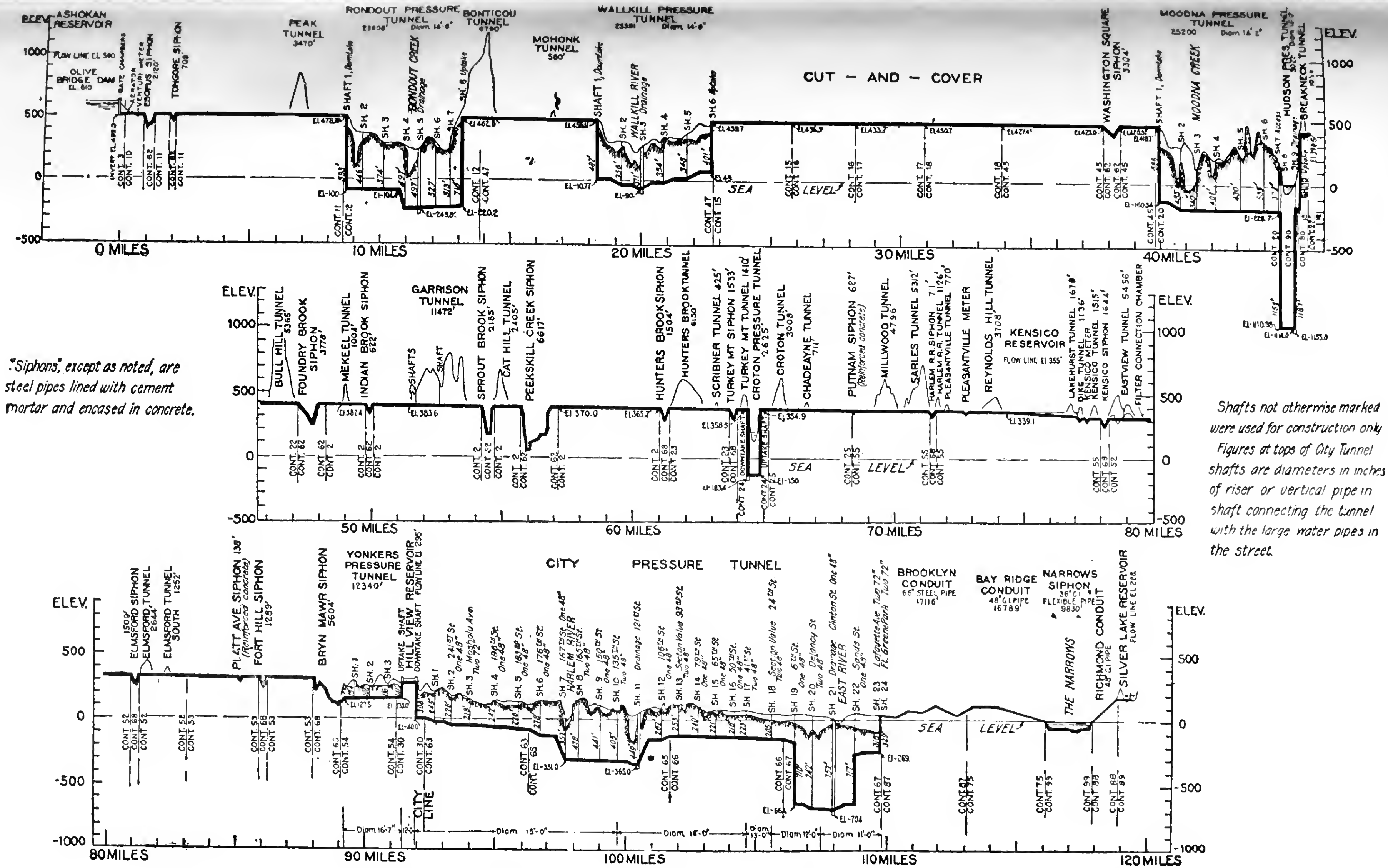


Fig. 4.—Catskill Aqueduct: Profile from Ashokan Reservoir to Silver Lake Reservoir.

Main Dam.

Length, 4,650ft.
Height, 220ft.
Thickness at base, 190ft.
Thickness at top, 23ft.
Width of reservoir (maximum), 3 miles.
Width of reservoir (average), 1 mile.
Depth of reservoir (maximum), 190ft.
Depth of reservoir (average), 50ft.
Villages to be submerged, 7.
Cemeteries removed, 32.
Bodies reinterred, 2,800.
Railroad being relocated, 11 miles.
Highways to be discontinued, 64 miles.
Highways to be built, 40 miles.
Bridges to be built, 4.
Earth and rock to be excavated, 2,936,000 cub. yds.
Embankment to be placed, 8,069,000 cub. yds.
Masonry to be placed, 984,000 cub. yds.
Cement to be used, 1,187,000 barrels.
Maximum number of men employed, 3,000.

The Kensico Reservoir.

East of the Hudson is the Kensico reservoir, 30 miles from the city hall (New York). This reservoir will contain several months supply of Catskill water, and will act as an emergency storage reservoir, so that the supply will not be interrupted in case of inspection, cleaning or accident on the 77 miles of aqueduct between it and the Ashokan reservoir. It is being constructed under contracts amounting to nearly £1,700,000. It will be formed by the Kensico dam across the valley of the Bronx River, about 3 miles north of White Plains, and 14 miles north of Hill View reservoir. Its normal flow level will be at an elevation of 355ft. above mean sea level, and will cover 2,218 acres. Its total capacity will be 38 thousand million gallons, and the available capacity will be 29 thousand million gallons, or about 60 days continuous supply at 500 million gallons daily, the present approximate total consumption of Greater New York. The maximum depth of water behind the dam will be 155ft.

General statistics of the Kensico reservoir are :—

Capacity, total, 38,000,000,000 gallons.
Capacity, available, 29,000,000,000 gallons.
Water surface, 2,218 acres.
Land acquired, 4,500 acres.
Elevation of water (full reservoir), above tide, 355ft.

Elevation of top of dam, above tide, 370ft.
Length of reservoir, 4 miles.
Length of shore-line, 40 miles.
Length of dam and dykes, 3,300ft.

MAIN DAM.

Length, 1,843ft.
Height, 300ft.
Thickness at base, 230ft.
Thickness at top, 28ft.
Width of reservoir (maximum), 3 miles.
Width of reservoir (average), 1 mile.
Depth of reservoir (maximum), 155ft.
Depth of reservoir (average), 100ft.
Highways to be discontinued, 14 miles.
Highways to be built, 9 miles.
Bridges to be built, 4.
Earth and rock to be excavated, 2,496,000 cub. yds.
Embankment to be placed, 2,003,000 cub. yds.
Masonry to be placed, 1,286,000 cub. yds.
Cement to be used, 1,224,000 barrels.
Maximum number of men employed, 1,000.

The work on the Ashokan dam has employed an army of 3,000, men, who have lived, many of them with their families, in a camp built by the contractors near the work. The work on the Kensico reservoir employed 1,000 men, who, with their families, lived a few hundred feet on the downstream side of the dam. An interesting feature of both these camps is a night school for the men. The school is operated by the Civic League of North America, and is encouraged and personally assisted by the commissioners. Other interesting features of these two camps are a savings bank, churches, hospitals, post-office, police and fire protection, children's day school, and a Young Men's Christian Association.

The cost of construction plant owned by the contractors at the Ashokan dam and the Kensico reservoir was, approximately, £500,000. The assembled plant of the Kensico reservoir, consisting of machinery, railroads, derricks, &c., owned by the contractors, cost about £200,000, while the plant for carrying on the work of the Ashokan dam cost much more than this amount.

When completed the Kensico dam will be a masonry structure 1,843ft. in length, with a maximum height of about 300ft. The top thickness of the dam just under the coping will be 28ft., and at the base of the maximum section will be more than 250ft. It will contain about 1,000,000 c. yds. of masonry. It will be a

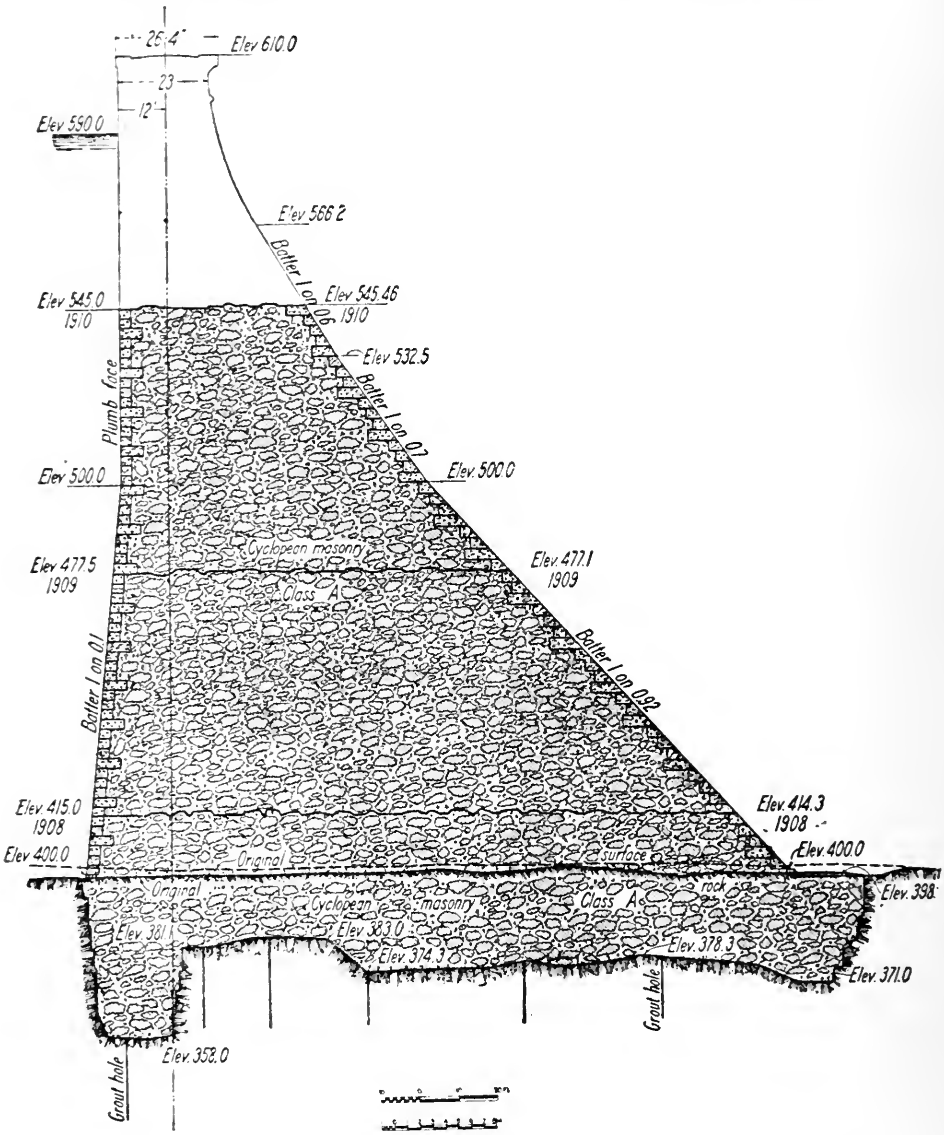


Fig. 5.—Olive Bridge Dam: Progress in Laying Masonry to January, 1911.

gravity masonry dam of cyclopean concrete. The upstream side will be of concrete blocks. The concealed portion of the downstream face below the final grading will be moulded against forms, above which the remainder of this face will be of granite masonry. The exposed portion will have a height exceeding 170ft. for more than 1,000ft. of its length. The entire dam is divided into sections by transverse expansion joints about 79ft. apart longitudinally; these expansion joints will be faced on one side with concrete blocks forming a series of vertical tongues and grooves against which the masonry of the inner side will be built. Near the upstream face a copper strip will be built across the expansion joint to act as a water stop, continuous from bottom to

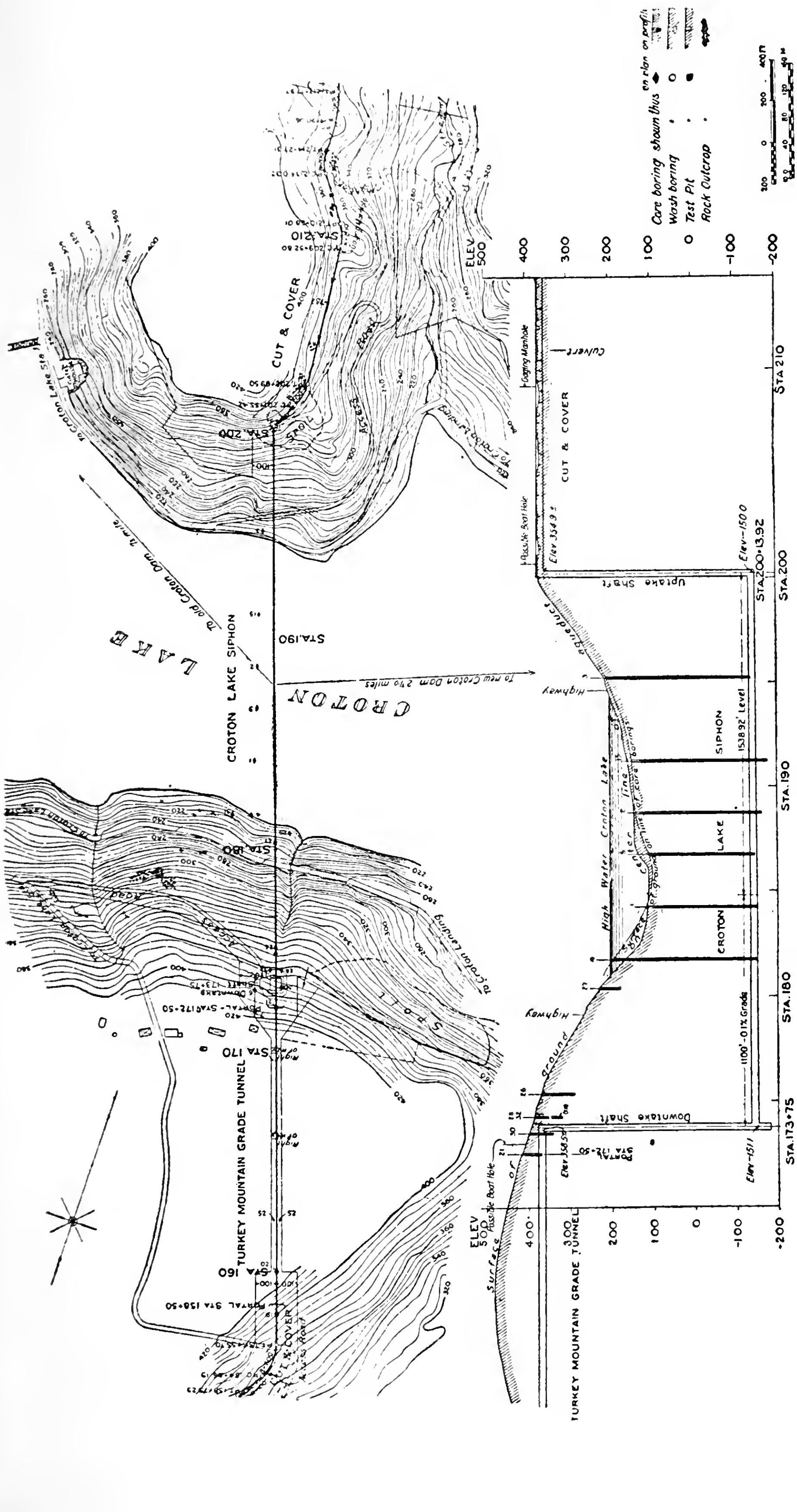


Fig. 6.—Croton Lake Syphon Plan and Profile.

top. Drainage wells 15ft. apart longitudinally, formed of porous concrete blocks, will extend from the top of the dam near the upstream face to an inspection gallery near the level of the reservoir bottom, which in turn connects with a transverse drainage gallery leading to the downstream face of the dam.

The lower part of the dam is being built by travellers, each equipped with two derricks, four travellers in a group of pairs facing each other across the space between the adjacent expansion joints. Tracks for these travellers, and for the cars bringing materials to them, extend across the valley, and are supported on concrete piers. This system of tracks and travellers is elevated from time to time as the masonry progresses. Two movable cableways of 1,860ft. span, on timber towers 125ft. high, stretch across the site, these being used principally for handling the equipment used on the masonry construction. The cables are of lock-bar type, 2·5in. in diameter. The towers can travel from the upstream face of the dam for a distance of 220ft. downstream, thus covering the site of the dam except the extreme downstream toe in the gorge. The lifting of the transporting apparatus is operated by wire rope from the head towers at the east end of the dam. The operating plant for each cable consists of an electric two-speed double-drum hoist.

Excavation for the Kensico dam was begun in 1911, and at the beginning of 1912 the old dam forming Lake Kensico had been breached, excavating in the old bed of Lake Kensico was in progress, the excavation of a flume for carrying off the water was completed, and the flume about two-thirds built. Excavation for a length of 250ft. at the west end of the dam was carried on by hand, the material being loaded into 2yd. skips, and removed by guy-derricks. At first the excavated material was used for grading for the cableway tail towers, but later it was used for fill below the dam. On May 20th the West Lake drive was closed, and the excavation was extended east. For 1,000ft. across the bottom of the Kensico lake the excavation was largely with steam shovels. The shovels removed both earth and rock, after the rock had been blasted, until the general level of the bottom had been approximately reached, after which the bottom was further excavated by hand.

The Catskill water conduit consists of four distinct types of aqueduct, namely, cut-and-cover, grade tunnel, pressure tunnel, and steel-pipe syphon. The cut-and-cover forms 55 miles of the aqueduct, is of horseshoe shape in cross-section, 17ft. high by 17·5ft. wide inside, and constructed of concrete. As completed it is covered with an earth embankment. This is the least expensive type, and so is used wherever the elevation and nature of the land permits. Where hills or mountains cross the line, and it

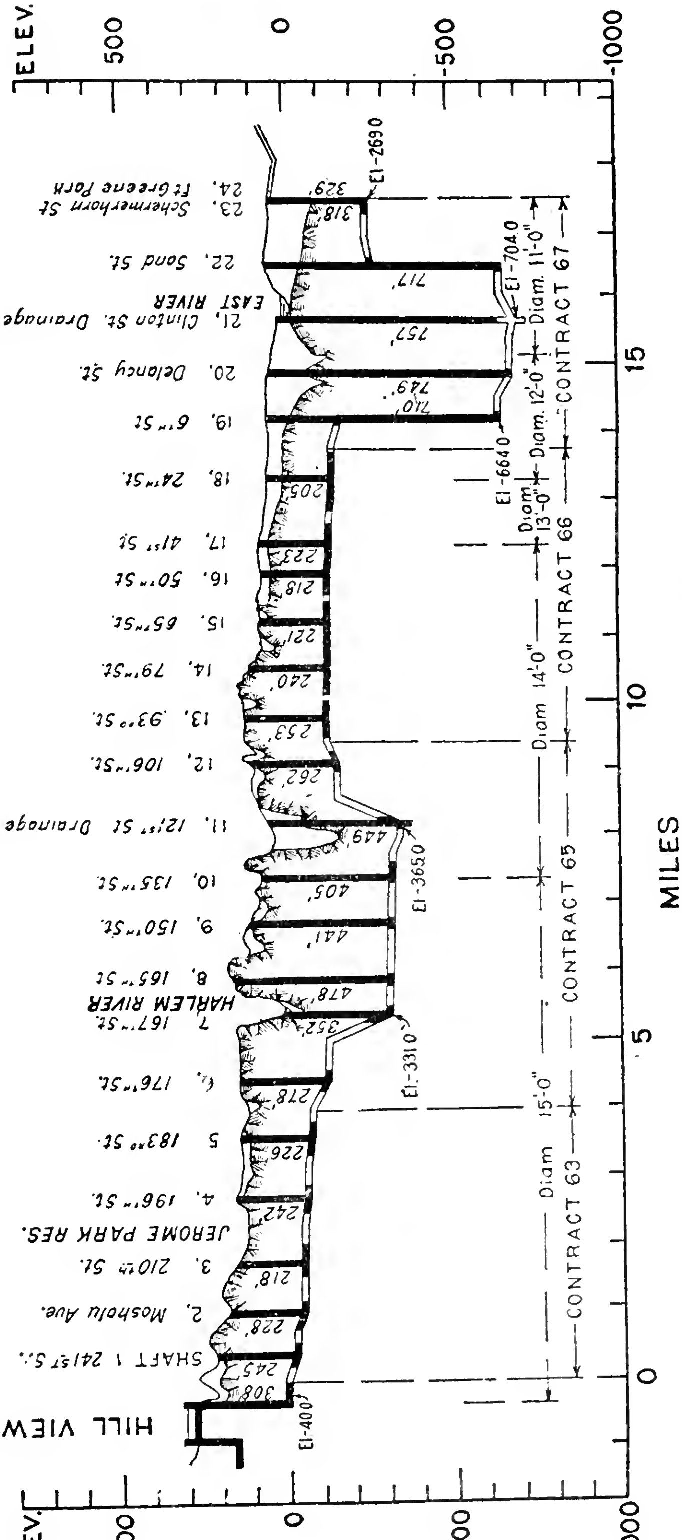


Fig. 7.—Progress in Excavation from Hill View Reservoir to Terminal Shafts in Brooklyn, shown by Full Black Section.

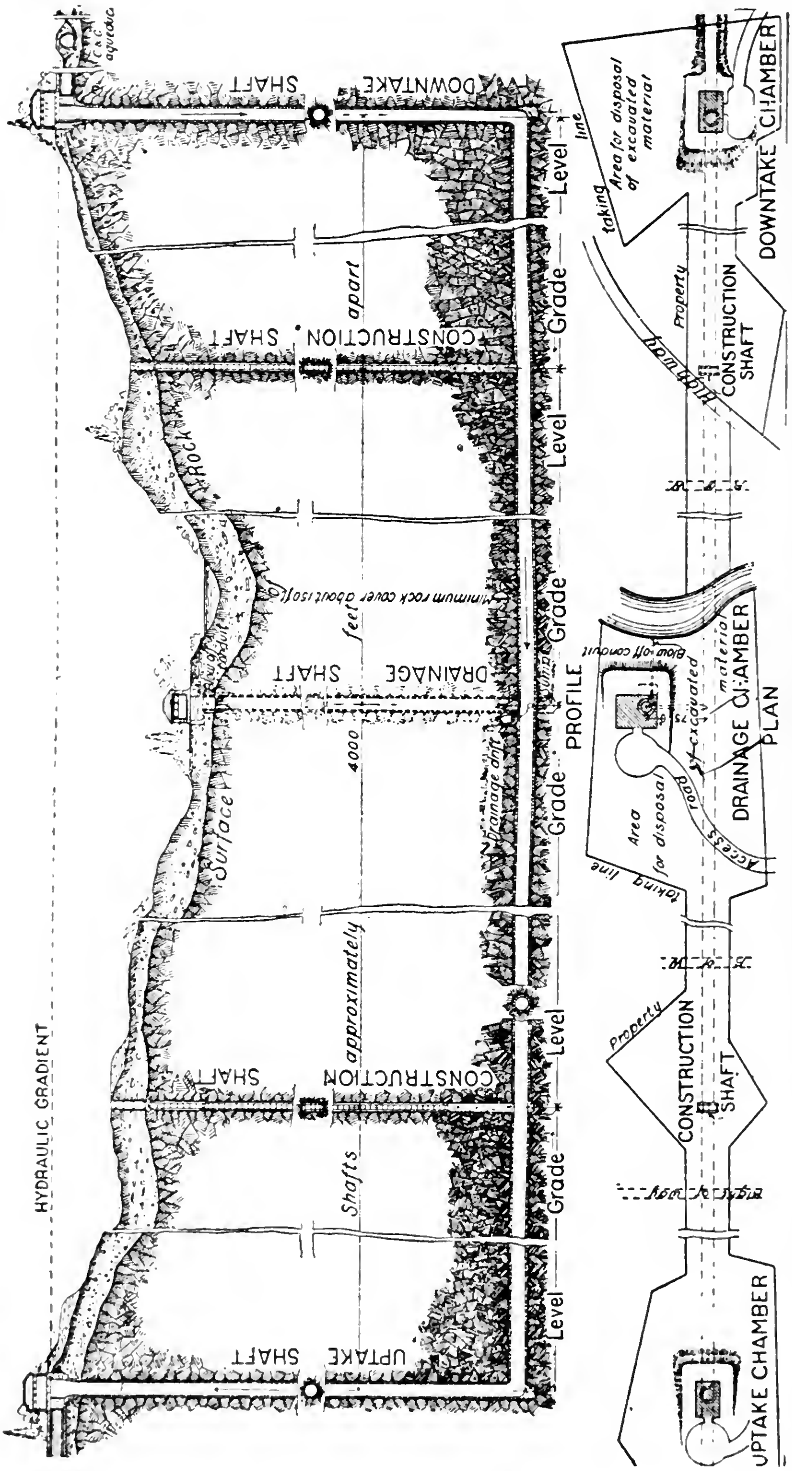


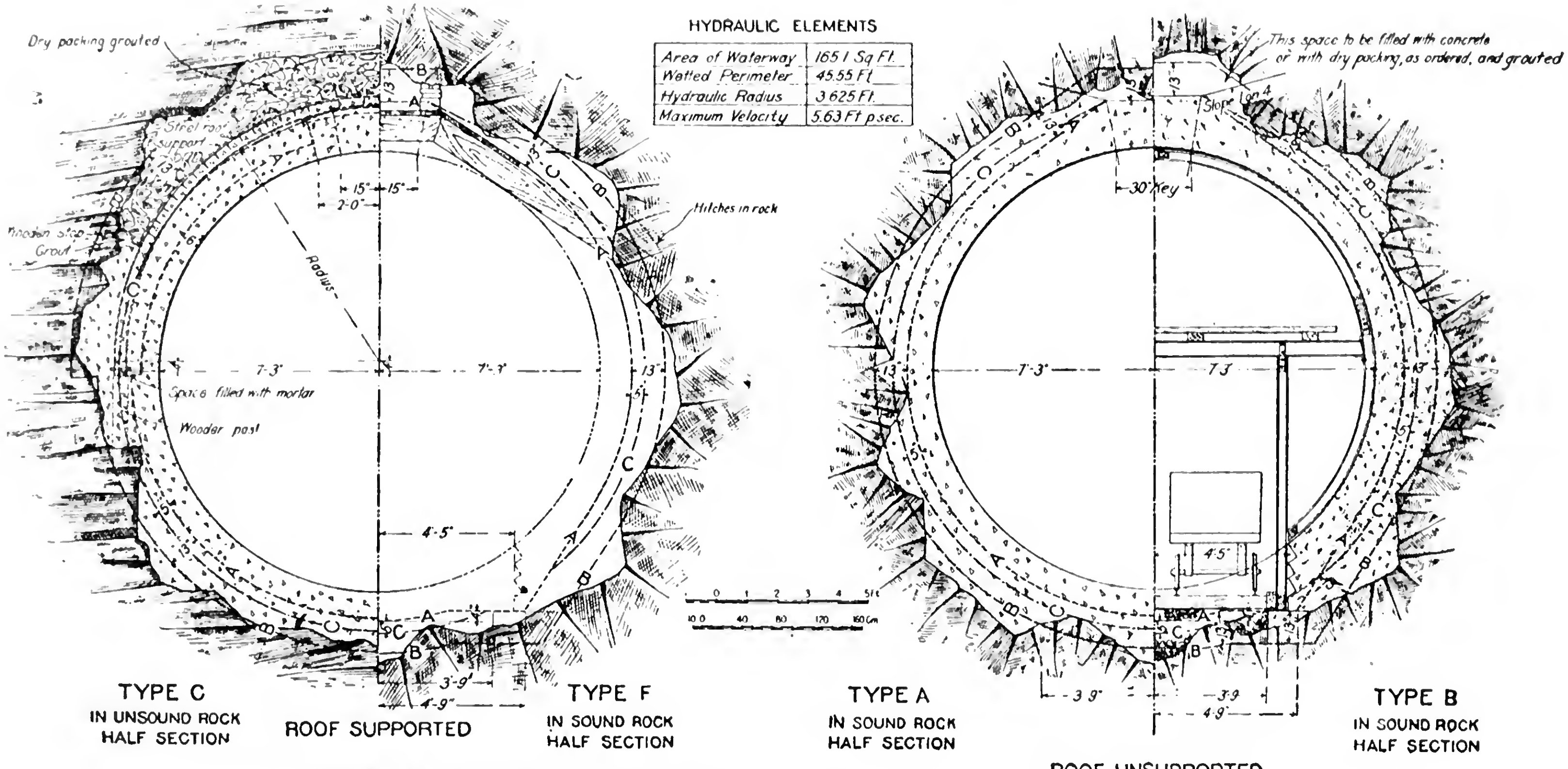
Fig. 8.—CATSKILL AQUEDUCT: TYPICAL PRESSURE TUNNEL.

would be impossible to circumvent them, tunnels at the natural elevation of the aqueduct are driven through them. There are twenty-four of these grade tunnels, aggregating 14 miles. These also are horseshoe shape, 17ft. high by 13·33ft. wide, and lined throughout with concrete. Where deep and broad valleys must be crossed, and there is suitable rock beneath them, circular tunnels have been driven deep in the rock and lined with concrete. There are seven pressure tunnels, having a total length of 35 miles.

Where the rock is not sound, or where, for other reasons, pressure tunnels would be impracticable, steel pipe syphons are used. These steel pipes are made of plates riveted together, and are 9ft. and 11ft. in diameter. They are lined with 2in. of cement mortar, embedded in concrete and covered with an earth embankment. There are fourteen of these syphons aggregating 6 miles. Three pipes are required in each syphon for the full capacity of the aqueduct.

Some Concrete and Metal Tests.

In the year 1912 a systematic examination was made of all waters encountered in tunnel work. A number of these waters were found to contain sulphates and chlorides of magnesium and calcium in such concentration as to be injurious if such waters were permitted to percolate through concrete for protracted periods. Special precautions were therefore taken to get dense and impermeable concrete in those portions of the tunnels in which such injurious waters were met. These waters were generally neutral or slightly alkaline in character, with the single exception of a water from one part of the city aqueduct, which showed an acidity equivalent to 8 parts per 1,000,000 of sulphuric acid. In order to discover what effect, if any, the water coming from the rock in the Hudson syphon would have on the concrete linings of the shafts, six 8in. by 16in. concrete cylinders of 1 : 1·96 : 4·24 mixture were immersed in the running rock water of one of the shafts of the Hudson pressure tunnel for two years. A similar set of six specimens was stored in the ordinary way in damp sand in the laboratory for the same period. When these specimens were crushed the two sets gave almost identical results, showing that immersion of this rich, dense concrete in the shaft water had not had the least effect upon it. The shaft water was of such character that considerable deterioration would undoubtedly have resulted if the water had percolated through the concrete, as was indicated by experiments carried out in previous years. In these experiments small specimens of concrete, purposely made lean as well as permeable by the use of sand composed of grains of practically uniform size, were found to be materially weakened after a year's percolation under pressure.



HYDRAULIC ELEMENTS

Area of Waterway	165.1 Sq Ft.
Wetted Perimeter	45.55 Ft.
Hydraulic Radius	3.625 Ft.
Maximum Velocity	5.63 Ft. p.sec.

THEORETICAL QUANTITIES PER LINEAR FOOT

	Type C *		Type F		Type A		Type B	
	10" to A line	12" to A line	10" to A line	12" to A line	10" to A line	12" to A line	10" to A line	12" to A line
Excavation Cu Yds.	10.81	11.22	10.17	10.53	9.95	10.31	10.17	10.53
Concrete " "	3.76	4.15	3.87	4.22	3.65	4.01	3.87	4.22
Packing " "	0.93	0.94	0.18	0.19	0.19	0.19	0.19	0.19
Grout " "	0.47	0.47						
Steel Ribs & Wall Plates Lbs	118.6	119.9						
Steel Lagging Lbs	248.60	248.60						

Invert excavation of certain types enlarged to permit placing sidewalls and arch simultaneously with excavation as indicated in Type B
* Quantities given assume dry packing complete over steel lagging
* Quantities based on 20 steel lagging panels per bent
* Grout 50 percent of dry packing
Excavation, masonry and packing quantities are computed to ideal average line of excavation, i.e. B line for all types

Fig. 9.—Types of Pressure Tunnel for Crossing Deep Depressions in Aqueduct Line.

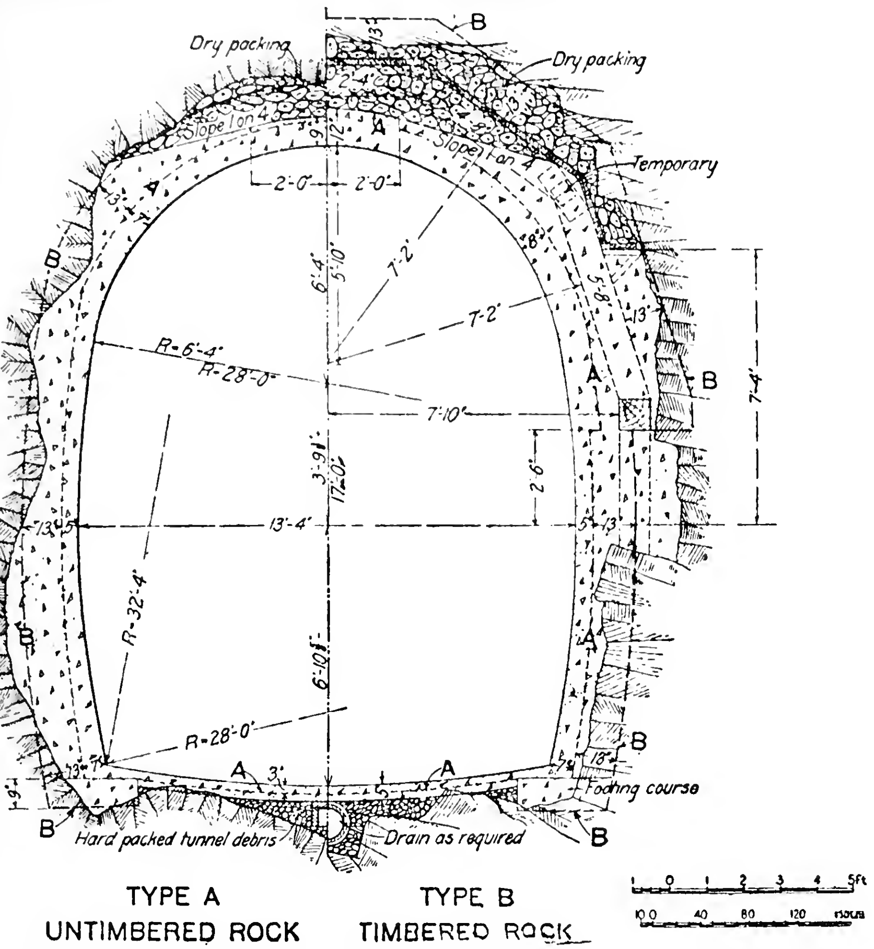


Fig. 10.—Types of Construction of Tunnel at Hydraulic Grade.

HYDRAULIC ELEMENTS

S-.00037

Depth of Flow Feet	Area Square Feet	Wetted Perimeter Feet	Hydraulic Radius
17	198.6	52.2	3.80
• 16.25	195.6	46.0	4.25
15.3	188.5	42.7	4.41
14	175.7	39.3	4.46
12	152.4	35.0	4.35
10	126.8	31.0	4.10
8	100.2	26.9	3.72
6	73.8	22.9	3.22
4	47.6	18.9	2.51
2	21.0	14.9	1.49
Maximum Velocity 4.8 Feet per second			

• Maximum Capacity.

THEORETICAL
QUANTITIES PER LINEAR FOOT

	Type A	Type B
Excavation, Cu Yds	10.2283	12.17
Concrete in Footings, Side Walls & Arch Cu Yds	2.3393	3.06
Concrete in Invert Cu Yds	0.1768	0.18
Timber for payment to Wall Plates M ft BM		0.118
Timber for payment below Wall Plates Est'd Average M ft BM		0.005
Tunnel Drainage Lin Ft	1.00	1.00
Dry Packing, Cu Yds	0.2958	1.22

TYPE A quantities based on arch 9 inches thick at crown

TYPE B quantities based on 10"x10" timbers 5'0" c to c. posts averaging 18" long

Excavation, masonry and packing quantities computed to ideal average line of excavation, i.e. B line.

For the Department of Bridges, 64 concrete specimens were tested. To determine the suitability of materials for construction 56 tests were made of specimens of concrete used on aqueduct construction, and 714 tests were made of concrete aggregates from localities along the aqueduct, including strength tests of mortar and concrete. All cement used in construction was inspected and tested, the records of these tests being :—

CEMENT TESTS.

	1910.	1911.	1912.
Barrels of cement tested	1,175,800	1,820,550	1,288,300
Per cent. accepted ..	95·44	90·31	93·46
Per cent. rejected (low strength)	1·09	0·43	1·03
Per cent. rejected (lack of increase between 7 and 28 days)	0·85	2·15	1·05
Per cent. rejected (excess in anhydrous sulphuric acid and magnesia) ..	1·70	4·31	—
Per cent. rejected (quick setting)	0·74	1·87	1·15
Per cent. rejected (falling off of strength) ..	0·18	—	—
Per cent. rejected (unsoundness)	—	0·60	3·31
Per cent. rejected (all causes)	4·56	9·69	6·54

A series of experiments was undertaken to determine the relative deterioration a metal suffers from corrosion when embedded in concrete alone and in contact with another metal. Weighed specimens of steel, manganese bronze, lead, copper and Monel metal were embedded in damp concrete singly, and in couples in contact. At the end of two months the concrete blocks were broken and the metals removed, cleaned, dried, and re-weighed. The resulting losses in weight showed but slight differences, whether the metals were alone or in contact, and gave no evidence of electrolytic action in the latter case. With the exception of lead the corrosion of all the metals was slight, that of Monel metal being almost nil. The action of lead confirmed previous experience, and showed that this metal may suffer appreciably in alkaline as well as in acid media; the corrosive action was observed to be solvent in character, no protective coating being formed to arrest further change. Specimens of iron and steel, 12in. by 24in. by $\frac{1}{4}$in. thick, from various manufacturers, were subjected to corrosive influences by exposure to the atmosphere and by immersion in Esopus creek. At the

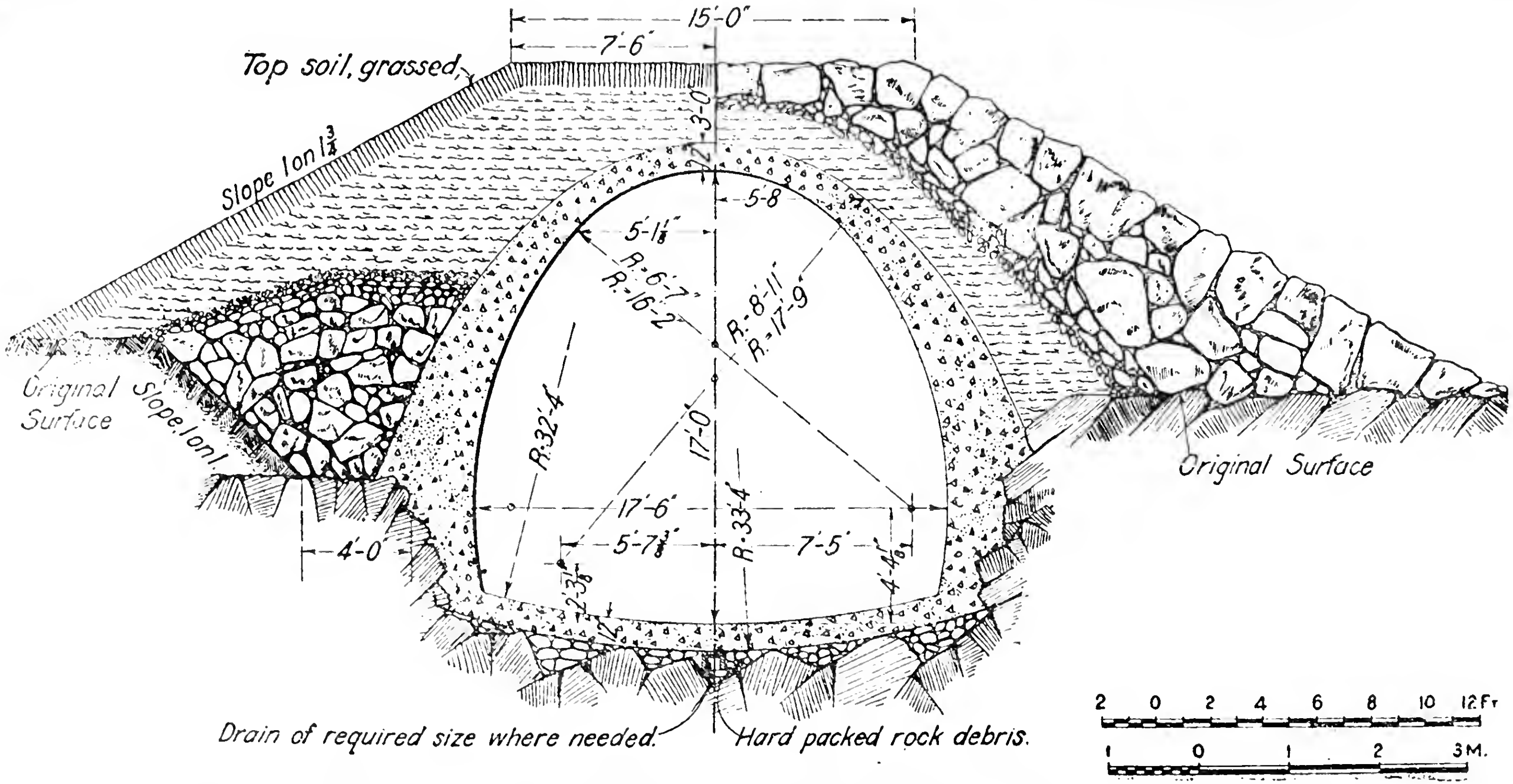


Fig. 11.—Typical Cut-and-Cover Construction in Partial and Total Rock Trench.

HYDRAULIC ELEMENTS
($S = .00021$)

Depth of Flow, Feet	Area, Square Feet	Wetted Perimeter, Feet	Hydraulic Radius
17	241.0	57.4	4.20
• 16.2	237.7	50.8	4.67
15.3	230.9	47.7	4.84
14	217.6	44.1	4.92
12	192.6	39.4	4.88
10	163.2	35.0	4.65
8	130.7	30.9	4.24
6	97.1	26.8	3.61
4	62.2	22.8	2.72
2	27.0	18.8	1.47
Maximum Velocity 4.0 Feet per second			

• Maximum Capacity

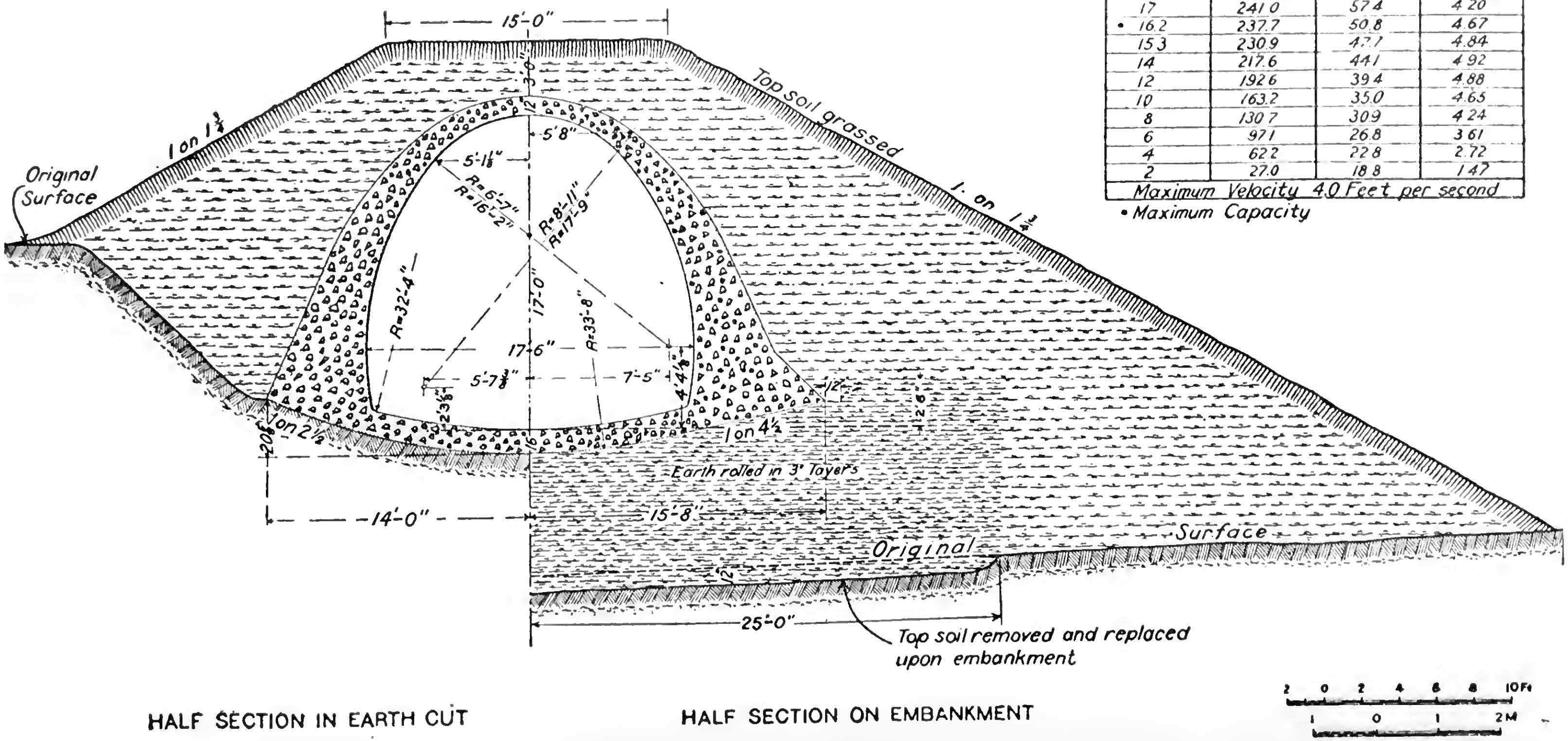


Fig. 12.—Typical Cut-and-Cover Construction in Earth Trench and on Embankment.

end of a year the specimens were cleaned of their accumulated rust with dilute sulphuric acid, while in galvanic contact with zinc, which effectually removed the rust without attacking the metal or scale, and were washed, dried and weighed. The relative deterioration of some of the metals, due to corrosion, are :—

Materials.		Loss per sq. ft. in grams.	
	(A)	(B)	(C)
Wrought iron	4	17·01	20·41
Especially pure, extra low carbon, open-hearth steel (*a*)	2	13·61	19·28
Especially pure, extra low carbon, open-hearth steel (*b*)	2	21·55	23·81
Open-hearth steel	4	17·01	18·14
Copper steel, containing ¼ per cent. copper	2	6·80	14·74
Bessemer steel	1	20·41	26·08

(A) is number of specimens in average; (B) is for exposure on laboratory roof; (C) is for immersion in Esopus creek.

Other series of similar experiments are being made, the metals being stored in various soils and kept continually wet, but no determinations of value have as yet been made.

To measure the water drawn from the big reservoirs some very large Venturi meters have been built on the line of the aqueduct. These are probably the largest water meters ever built. There is one just below Ashokan reservoir, a second just above Kensico reservoir, and a third where the water is drawn from Kensico reservoir. Each of these meters is 410ft. long, of reinforced concrete, except for the bronze throat castings and the piezometer ring, which is also of cast bronze.

APPENDIX.—I.

Engineering Achievements and Activities in Greater New York.

	£
Amount spent on harbour improvements ..	3,700,000
Spent (1912) on subway construction ..	3,000,000
Spent (1912) on Catskill aqueduct system	5,000,000
Value of industrial products (per year) ..	400,000,000
Manhattan piers	5,000,000
*Barge canal	22,000,000
Dredging of bay at Long Island	200,000
New building, Grand Central station ..	400,000
Pennsylvania terminal	32,000,000
Hudson and Manhattan tunnels	14,000,000
Belmont tunnel	1,700,000
†Subway and elevated railways	60,500,000
Inter. Rapid Transit Company	25,000,000
Brooklyn Rapid Transit Company	12,000,000
Manhattan bridge	2,800,000
Williamsburgh bridge	2,800,000
Blackwells Island bridge	2,700,000
Interstate bridge (179th Street, Manhattan)	10,600,000
Municipal building (just finished)	4,000,000
Woolworth building (60 stories)	2,600,000
Sewerage system	3,000,000
New Catskill aqueduct (total cost)	40,000,000
Total expenditure for waterworks, including Catskill system	60,000,000
Total expenditure during the past few years for private, public and semi-public undertakings (approximate total)	200,000,000
Total traffic of the harbour (annually), 100,000,000 tons.	

*This barge canal has sixty-eight modern concrete locks, a total liftage of 1,070ft., as against the total liftage in the six pairs of gates at Panama, of 170ft. It represents a total excavation of 114,100,000 cub. yds., as against 203,000,000 cub. yds. at the Isthmus of Panama. The amount of concrete used is not far below that used on the Panama Canal locks. Its length is over 300 miles, as against 50 miles across the Isthmus.

†The Board of Public Utility Commissioners of New York approved of the financing and extensions of the lines of the New York Central Railroads (December 20th, 1913). Under the plans submitted it is estimated that the New York Central and affiliated companies will spend approximately £80,000,000 in the next ten years.

*Height of Woolworth building, 750ft.
Height of Metropolitan tower building, 700ft.
Height of Singer tower building, 612ft.
Buildings above ten stories, 1,200.
Telephone connections, daily, 2,000,000.
Miles of underground wire, 1,200,000.
Number of telephones, 500,000.
Capacity of the largest power station, 500,000 H.P.
Number of lamps supplied (over), 5,000,000.
Tons of coal burnt daily, 2,000.
Capacity of the new water supply system (daily capacity), 500,000,000 gallons.

*In this building are the highest rise-elevators in the world, two of which have a rise of 680ft., as against 450ft. provided in the Eiffel Tower, Paris. In the latter three elevators are used to reach a height of nearly 1,000ft., the highest rise of a single elevator being approximately 450ft. Plans have lately been approved for a skyscraper," to be called the " Pan-American " building, which will be higher than the Woolworth building, at present the highest building in the world.

APPENDIX.—II.

Inhabitants of Greater New York.

As estimated, July 1st, 1913, by the Department of Health, the inhabitants of Greater New York number 5,373,000 ; but the whole community directly dependent for existence on the New York Harbour is far greater, and aggregates nearly 6,800,000. Of this inhabitance, 12 per cent. live in areas having a population density of 400 or more per acre, and 11 per cent. in areas having 10 or less per acre. The total number of foreign-born are :—

From Russia	485,000
,, Italy	340,000
,, Ireland	253,000
,, Germany	280,000
,, Austria	193,000
,, Hungary	73,000
,, England	78,000
,, Sweden and Norway	57,000
Jews	more than 1,000,000
Negroes	121,000

In New York there are enough Turks and Balkans to fill twelve cities as large as Cettinje.

New York's two-year growth would people a Nottingham. New York's five-year growth would people a Liverpool.

DISCUSSION.

The **President** (Mr. H. C. H. Shenton) said it was to be regretted that the author of the paper was not in England at the present time. The subject of the paper was of the very greatest importance, because it not only dealt with the largest waterworks in the world, but it was, he believed, the first paper on the subject that had been read before a representative engineering Society in this country. That night it had been read before two representative English engineering societies, and it therefore became doubly important.

Probably one of the first things which struck one in reading the paper was that the author did not state his authority for coming before them with description of work which was not his own, and upon which he had apparently not been employed, and it seemed strange that at first there was no acknowledgment of the source from which the information was obtained and the drawings—which were quite familiar—were taken. But it went without saying that a paper like that was not accepted without such matters being looked into as a preliminary, and he ought to say that Mr. Taylor had the best authority for his statements and the use of the illustrations—that of the Chief Engineer of the Board of Water Supply of the City of New York. He (Mr. Shenton) had before him the letter from Mr. Taylor in which the latter told them that Mr. A. D. Flynn, the departmental engineer on the work, and the author of many well-known papers on the subject, had presented him with a complete set of reports dealing with the scheme and all other available data and drawings, and the matter was delivered to him at the Engineers' Club, New York, with the compliments of the Chief Engineer. He ought to mention also that not only had the New York Water Board empowered Mr. Taylor to write that paper to be read before a British Institution of engineers, but they had at the same time sent copies of their reports to the Institution of Municipal Engineers, and these valuable publications were therefore available to the members of that body for reference. That showed, he thought, the very friendly feeling American engineers had towards them.

The mention of the Engineers' Club made one sorry there was not some similar club in London. Mr. Taylor, he might tell them, was a mechanical and hydraulic engineer in private practice in New York, a member of the American and British Institutions of Civil Engineers and other societies, and he had also had an eventful military career. That was, however, beside the subject of the paper, but as he had to propose a vote of thanks to Mr. Taylor, he thought they would like to know something

about him and his authority for writing the paper. The author had been able from the sources stated and from personal investigation to gather special information with regard to his subject.

The paper was, of course, general rather than particular, and to that degree he was rather disappointed, becaused there were so many points of detail in the scheme that well deserved discussion. There was mention in it, for instance, of concrete-lined tunnels, but it was one thing to line a tunnel and another to make it watertight, and the methods employed in doing that were of interest. The lining of steel mains with cement was also very interesting, and there was a great deal to be said about that, and there were innumerable other matters of particular interest which ought at some future time to be discussed by the Society and the Institution. He did not propose to discuss the paper now, but he asked them to accord a vote of thanks to the author.

The vote of thanks was carried with acclamation.

Mr. E. Sandeman said it was difficult to avoid being very greatly impressed with the magnificence of these works and with the efficient methods of the engineers. When one considered that the 500 million gallons of water which New York was going to take in was simply supplementary to their existing supply and was sufficient to supply half of England, it gave some conception of the vastness of the scheme. Having been engaged for twenty years in the construction of impounding dams it was natural for him to turn to the section of the Olive Bridge dam. As they had already heard explained, the whole length of the embankments and dams was about 5½ miles, but the masonry part was only a very short length of that mileage. The dam he had referred to apparently had a thickness of 190ft. at the base.

Some fifteen or twenty years ago New York built the New Croton dam, which was higher than the one under notice and a much thinner one. When proposed, as it was going to be one of the biggest in the world, a special Board of Experts—that of the engineers of the Aqueduct Commission—was called together to consider the design. The Board thickened the dam considerably, probably on account of the ice pressure which might affect the structure, but, notwithstanding the decision of the Board of Experts, the design was again altered, and the thinner section was adopted.

It was interesting to compare what had been done in those two designs. At 50ft. from the top the New Croton dam was 34ft. thick, but this new dam would be 53ft. ; at a 100ft. from the surface the New Croton dam was 72ft. thick, but the Olive Bridge dam would be 93ft. ; at 150ft. from the top the New

Croton dam was 156ft. thick, whereas this new one would be 154ft. So it was 20ft. thicker practically the whole way down. There must be some strong reason for that increased thickness as it now appeared that the engineers had reverted to the thicker design originally proposed by the Board of Experts. The effect of making the dam so thick was to give it increased strength, and whereas the Croton dam had a factor of safety of rather more than two, this would have one of $4\frac{1}{2}$.

There was another peculiarity about it. The resultant of the water pressure and the weight of the dam combined struck the exact middle of the dam, so that when the dam was full of water there was an exactly even pressure over the whole base. When the dam was empty, the pressure on the up-stream side seemed to be about $11\frac{1}{2}$ tons, and on the down-stream side apparently about half a ton. The weight per foot down to about 180ft. was about 1,000 tons. In the dams which he had just been finishing in the Derwent Valley, down to about a similar level the cross section would weigh about 880 tons, so that the Olive Bridge section was a much heavier one.

He noticed that a great part of the embankment was formed in the American fashion with a concrete core instead of puddle as used here. It seemed somewhat surprising that the Americans did not use puddle if it were available, because one could not help thinking that where large embankments were made with a central core, that the core must of necessity be bent to one side by the settlement of the earth unless a reinforced core were adopted. It was difficult to make an embankment that would settle exactly evenly, and the pressure was almost bound to come on one side of the core.

A noteworthy point was the rather high cost of the plant employed on these works. £500,000 invested in this way on two reservoirs seemed very large, but it was difficult to grasp what plant was required unless one had more details.

Dr. Herbert Lapworth congratulated the members on having this interesting account of American engineering practice placed before them. He supposed many English engineers were rather inclined to think they had not much to learn from American engineering practice. That might have been true possibly fifty years ago, but he thought that at the present time they had a great deal to learn from them ; certainly as regards water supply the Americans had the finest literature in the world. The Catskill scheme was of very great interest to water engineers in this country, and they could learn a great deal from it. It was without parallel in the history of waterworks engineering, not only by reason of its heroic dimensions, but also by reason of the ex-

tremely careful investigations from which the designs were prepared and the painstaking attempts made to effect economies in location ; and lastly, by the extraordinary rapidity with which (in spite of these exhaustive preliminaries) the work had been carried out.

In a paper like the one before them the subject was too vast to go into details, but there was one point of the utmost importance, namely, the question of the geological investigations. Throughout the whole of the scheme geology had played an essential part, and the location and designs were based largely on the results of geological investigations. The methods adopted in crossing wide and deep rivers afforded a good illustration of the care and yet boldness with which everything was done. When they considered the scheme in all its aspects he thought it would be agreed that even the most experienced of them must greatly benefit by the study of its details.

Mr. Horace Boot (President of the Institution of Municipal Engineers) observed that the subject of the paper was of great interest to municipal engineers, especially in this country where one was struck by the small, inadequate water schemes which were so often carried out by our municipalities. If they traced the history of the water supply of our great towns they found that the town councillors generally could not bring themselves to realise that their cities must grow and the requirements increase. In tackling a water supply they should not be afraid of dealing with it on a large scale. He thought the thanks of the two societies were due to Mr. Taylor for sending over a paper of such great interest. It would have one effect, he thought : in the future when they came to design a water scheme they would be encouraged to put forward a sufficiently large one.

One would have liked to see the analyses of the water for drinking purposes, also what Mr. Taylor expected would take place with regard to the expansion of the steel pipes. Mr. Taylor coated many of these pipes with concrete. In this country, if we were to treat water pipes in that manner, he was not altogether sure that it would be successful.

To be able to judge a scheme like that of New York one required to know something of the quantity and quality of the water, the capital cost of the work, and the selling price of the water before one could judge whether the scheme was going to be an engineering success. It was not difficult to design a scheme costing millions of money, provided that money did not matter. He did not for one instant suggest that in this particular scheme that point had not been borne in mind, but it was useless for engineers to put forward a gigantic scheme without regard for these important items.

In one part of the paper the author spoke of the trouble arising from lead corrosion. If that were gone into a little closer it would probably be found that it was set up by the presence of dissimilar metals causing electrolytic action rather than by corrosion.

Mr. Taylor had included in his paper a rather elaborate diagram of the organisation of the engineering department, and there again it was quite possible that in this country their water schemes were not sufficiently organised. In one's travels abroad one could not but be surprised by the magnificent organisation that existed in such matters, and especially in water departments.

Mr. Percy Griffith said he thought it was right to say that they were proud (with their confrères the Municipal Engineers) to be the first of the societies in this country to have a paper on this important subject read and discussed. He was bound to say that he considered the paper a very valuable and interesting forerunner of what would no doubt be available in greater detail later on. A great scheme had been undertaken and an important section of it was nearing completion.

In the paper they had a general summary of the dimensions, scope, cost, and other interesting features relative to the work. The figures presented to them did not tell them much more than that the scheme was a stupendous one, and one representing an epoch in the history of water engineering. That was enough to make the paper welcome and worthy of discussion.

Their attention in these days was so often monopolised by small details that they were unable to take a broad and comprehensive view of any large scheme. It was for that reason that he thought it useless to raise certain questions that had occurred to him, questions in the nature of "asking for more."

There was one matter, however, that he would refer to, namely, the relationship between the storage and the flow of the stream in each case. He was not sure whether or no the information was published in book form and available to them at their leisure, and if so he would not criticise the author for not giving details of that nature. The question of the relation between the dimensions of the scheme and the population to be supplied reduced itself to the quantity of water required per head per day. He had not before him the proportion of the supply in New York required for trade and municipal purposes, but he knew that the so-called domestic consumption was in most American cities very large, while experience showed that health and sanitary conditions could be maintained on a much smaller quantity. It was a serious question whether it would not be worth while to attempt some reduction in the consumption of water rather than to spend enormous sums on gigantic water

schemes such as the one described in the paper. A comparison between the expenditure necessary to reduce consumption and the expenditure necessary to increase the supply seemed worth consideration, and he would like to know something of the figures which would apply to this case. He did not hesitate to suggest that it would be more economical to check unnecessary consumption.

Mr. J. D. Haworth remarked that a consumption of 100 gallons per head per day appeared enormous. In Manchester, he believed, it was only from 40 to 42 gallons, in spite of the large consumption on account of the various trades carried on in that city. His own experience was that the supply to the ordinary consuming population should not exceed 20 gallons per head, and he had known it to be even as low as 15 gallons where means of preventing waste were adopted.

Referring to Fig. 12 in the paper, he thought there must have been some special reason for the Board of Experts constructing a concrete culvert on foundations of the nature shown on the section. For his own part he would be very diffident in putting such a structure as the one illustrated on a foundation of filled-in earth, even when rolled. There was always the difficulty to be borne in mind of the filling material not consolidating sufficiently. If any settlement took place in the filling after the culvert was constructed a fracture might occur in the concrete, which would not only be difficult to repair, but cause serious inconvenience. It would be interesting to know what were the reasons which led the Board to decide on the method of construction adopted in the dam.

Dr. S. Rideal remarked that he had had opportunities of studying on the spot the question that had been raised by Mr. Griffith and Mr. Haworth. He believed the population of New York was now approaching six millions, and they certainly used more than 100 gallons per head per day. The Sewage Commissioners were calculating on a population of 9,000,000 in 1940. He thought with Mr. Griffith that the consumption of water could be considerably reduced in the future, and many American towns were now being metered. It was a curious fact that, although New York had a larger water consumption than either London, Paris, or Berlin, the death rate of the former was higher than that of any of the other three. It was noteworthy that in Mr. Taylor's paper there was not a word about purification, and they had to ask themselves what was going to take place in these large reservoirs. The large quantity of water was going to be very short of oxygen in time, and would encourage all sorts of growths, so that

before it arrived in New York he expected it to have a smell, a colour, and a taste. The experimental aerators were giving good results, but probably other methods of purification would be required.

Dr. Eric Rideal followed with some remarks regarding the choice of steel in preference to wrought iron pipes, and the protection of pipes by means of cement.

Prof. Alex. H. Jameson said he recommended members to read the book recently published, *The Catskill Water Supply*, by Lazarus White (Wiley & Co.), which was splendidly illustrated, and gave a very full account of the construction methods and plant used in the New York works. As to filtration, he called attention to Fig. 4, in which, at 80 miles on the section, a filter connection chamber was marked. That was not, he thought, marked on the original drawings, but looked as if the idea now was to filter the water south of the Kensico reservoir. He thought it would be more advisable to filter the water at the head of the aqueduct so as to avoid organic growths therein, and he could point to the experience of Manchester on their Thirlmere aqueduct, where frequent cleaning of the cut and cover and tunnels was necessary to remove evil-smelling *Spongilla*, etc. That was a matter of considerable difficulty in unlined tunnels, and he was therefore glad to see that the Catskill tunnels were lined with concrete.

The cut and cover section was quite different to our British practice. The idea seemed to be to have shallow excavation and no timbering of trench, allowing the use of steam excavators and using the spoil for an embankment on top of the conduit, which got very little support from the sides of the trench, and was therefore of a horseshoe section. The author referred on page 170 to its " skirting many a steep hillside," but the many photographs in Mr. White's book all showed the ground as nearly level across. For " steep hillsides " the type of section shown in the author's paper would not, he thought, be suitable on account of the risk of landslips and surface creep, unless the trench were cut much deeper, and then a section deriving more support from the sides of the trench would be more economical. In bad cases, however, a lateral tunnel would be the best. His experience was that concrete became worn and pitted after a time by moving water, the velocity varying from 4ft. per sec. in the Catskill cut and cover to 4·8ft. per sec. in the grade tunnels and 5·8ft. per sec. in the pressure tunnels. He thought a vitrified brick facing to the invert, at least where the wear was greatest, would have been found to be advantageous.

The pressure tunnels were certainly the most novel feature of the aqueduct, although there was a valuable precedent for them in the pressure tunnel 7 miles long under the Harlem River on the new Croton aqueduct for New York city. They necessitated an immense amount of boring to locate in suitable watertight rock, but when constructed were absolutely permanent; no maintenance was required, there was no danger of burst pipes and no costly automatic arrangements to mitigate their effects.

Under the Hudson River and Croton Reservoir, undoubtedly, pressure tunnels were by far the best form of construction, as also under New York City for security and in order to avoid the enormous disturbance of the streets and cost of laying the equivalent thirty-two 48in. pipes or the sixteen 66in. pipes, but he questioned whether it was economical to construct them for the Rondout, Wallkill, Moodna and Yonkers syphons, which aggregated 16 miles, or nearly half of the total length of pressure tunnels (35 miles). The steel pipe syphons, of which only 6 miles were constructed, formed in reality a reinforced concrete aqueduct of great strength and permanence, and had the advantage of far greater accessibility than a pressure tunnel, and would, he suggested, have cost far less for the above four syphons. Three of such steel pipe syphons should not have cost more than twice as much per foot as the cut and cover, and, allowing for the saving of interest on capital by laying each pipe only when demanded by the consumption, they would probably not have cost more than $1\frac{1}{2}$ times the unit cost of cut and cover, whereas Mr. White stated that pressure tunnels cost $2\frac{1}{2}$ times the cost of cut and cover per unit length.

Possibly the engineers had doubts as to the durability of the steel pipe syphon construction, but there seemed every reason to expect that it would be a success and solve the difficulty of the incrustation of pipes, with consequent greatly reduced delivery and necessity of renewal. He might point out that the pipes, after riveting together and caulking, were tested at working pressure, then concreted outside, while filled with water, to a thickness of from 6in. to 18in. in a horseshoe section. The water was drawn off, and the 2in. internal lining formed of 2 to 1 cement mortar by screeding the invert and grouting the remainder behind flexible wooden moulds. Experiments of two years' duration made in Croton water with naked steel plates, plates embedded in cement, and plates separated from the cement by a $\frac{1}{25}$in. gap, showed respectively great corrosion, perfect condition, and very slight incrustation of the steel plates, indicating that even when the cement did not perfectly adhere it neutralised the acidity of the water and prevented rusting. There were only 16 miles of ordinary pipe line, wholly in the delivery area.

Mr. Henry C. Adams said that he thought it was recognised to some extent that the immense quantity of water delivered to New York was not actually consumed or used by the people, but that large volumes were wasted. Whatever the facts were, the problem of distributing the water supplied by this scheme was one of great importance.

Calculating the water consumption on the usual per capita basis, a sufficiently accurate result would no doubt be obtained in the bulk, but when considered in detail, the size and character of both population and buildings varied to such an extent that the estimate was likely to be a long way out. The waste could be divided into two parts, that from the mains and that from the house services, the relative proportion of each depending on different circumstances. In general terms it may be stated that the waste from the mains is proportional to their total length, while the waste from the house services is proportional to the population. The engineer in whose hands the distribution of the water had been placed had adopted the novel method of basing the consumption on the floor area. He assumed that the amount of water used in each building was proportionate to its cubic contents, or, more strictly, to the floor area in the building, which was arrived at by taking the ground area of the building from the maps and multiplying it by the number of floors, adopting 1,000 sq. ft. as the unit of area.

In order to be satisfied that this basis was a satisfactory one, it was checked by observations made in two representative areas, one containing high-class property and the other tenement property. It was found, after counting the inhabitants in the two blocks, that the consumption in the former area was 128 gallons per head per day, while in the tenement property it was 31 gallons. Basing the consumption in these two districts on the floor area, the consumption in the high-class dwellings was 151 gallons per 1,000 sq. ft., and in the other 149 gallons ; it is therefore apparent that much greater accuracy would be obtained by designing the distribution system on the basis of the floor area.

Of course they must bear in mind that the figures quoted were United States gallons, and they ought, therefore, to take off 17 per cent. to get British gallons, but there was no doubt that in America more water was used than was the case here, while in summer large quantities were used for cooling purposes. At the same time the waste was far greater than the use, and that was the reason why meters were being adopted so much on the services. Generally, a meter had the result of reducing the quantity of water lawfully used, and to that extent was undesirable, but it also prevented waste, and that had proved to be the case in many other cities where the consumption had been reduced from about 100 gallons to 50 gallons per head per day. What took

place was not a reduction in the ordinary domestic consumption ; it meant that the waste had been noted and stopped because the people had to pay for it. Chicago, with only 6 per cent. of the services metered, used 237 gallons ; Philadelphia and Denver, with 1 per cent. metered, used 200 and 231 gallons respectively per head per day.

Mr. William B. Bryan wrote :—I have for many years past been exceedingly interested in the works that have been designed and carried out in connection with the New York water supply. I am fortunate in being the possessor of most of the official reports in connection with the various schemes and works, and I must say that the boldness of some of the projects and the manner in which they have been executed has my highest admiration. Mr. Taylor's paper gives in a most excellent manner the leading features of this gigantic scheme, and I much regret my inability to be present to take part in the discussion.

Mr. W. J. E. Binnie sent the following written communication: There are so many novel features of construction in connection with the Catskill water supply for New York that it is difficult to do justice to the subject in a short paper such as Mr. Taylor's, whose notes will, however, bring home to those who have read them the gigantic nature of the undertaking.

Dealing first with the Olive Bridge and Kensico dams, several features of design call for remark. The use of concrete blocks for facing the upstream and downstream faces of the dam is very convenient, as it avoids all false work, and is to be recommended where suitable stone cannot be obtained at the site of the works. The dam across the River Alwen in Wales, now being constructed for the Birkenhead Corporation, is being faced with concrete blocks in a similar manner. The blocks on the upstream or water face are smooth, but those on the downstream face are cast in special moulds so as to imitate rock-faced masonry. The concrete next the face is made with an aggregate consisting of 3 parts of stone and sand to 1 part of cement, the rest of the concrete being 5 to 1 and the stones in each case measuring not more than 2in. in any direction. All the blocks are made on a vibratory table to increase their density.

There are two masonry dams in this country where expansion joints have been adopted. The first was the Upper Neuadd dam, designed by the late Dr. Deacon, in which asphalte expansion joints were introduced. These joints prevented any cracking of the masonry, and remained perfectly watertight for ten years, when one of these allowed a small quantity of water to pass between the asphalte and the concrete and masonry, but this leakage was readily caulked, and was no doubt due to the diffi-

culty of getting perfect adhesion between asphalte and concrete or masonry, where it is impossible to heat the surface before the asphalte is applied. The other dam was designed by Messrs. Meik for the village water supply at the British Aluminium Co.'s works at Loch Leven, and is described in Mr. Roberts' paper (see Proc., Inst.C.E. Vol. CLXXXVII.). I understand that these joints, which were spaced 80ft. apart, have proved satisfactory and have prevented cracks in the body of the dam.

It is difficult in a dam of the dimensions described in Mr. Taylor's notes, to bring up the concrete in regular horizontal layers throughout, and the introduction of slip joints faced with moulded blocks, as described in the paper, permits of different portions of the dam being brought up to different levels at the same time. It would add to the interest of the paper if the author would furnish details of the copper strip which was introduced across the expansion joint to form a stop for the creep of water.

The elaborate system of internal drainage by means of vertical wells communicating with horizontal galleries, referred to in the paper, should prevent any turning moment of importance being brought about should water penetrate along a horizontal crack or plane of weakness, which is liable to occur at the junction of old and new work unless great care is taken.

In addition to the Olive Bridge dam the Ashokan reservoir is formed by embankments known as the Beaverskill Dykes, about 2½ miles long, the maximum height of the embankment being 115ft. above the ground surface. The usual English practice is to provide an impermeable core wall of puddle in the heart of the embankment, and a concrete cut-off wall below ground level. In the case of the Beaverskill dykes the core wall is of concrete both above and below ground level, being 4ft. thick at the top with a batter of 1 in 20 on each face to ground level. The advantage of having a concrete core wall throughout is that if any leakage occurs there is no liability to erosion, and therefore the leakage does not tend to increase. With puddle, once a leak commences, erosion is found to follow until the safety of the whole embankment is endangered. No doubt one reason that English engineers have not looked with favour on the concrete core wall above ground level, is due to the fact that a wall of concrete is liable to crack, and another reason is that puddle clay is often obtainable at small expense near the site of the works.

In the case of the Beaverskill dykes no special means appear to have been taken to lead any water safely away which might penetrate cracks in the concrete core walls, and this would appear to be a desirable provision. All who have had to do with embankment works realise the great care which must be taken with the puddle core to ensure an absolutely watertight septum to

prevent creep of water, and it appears that the time has arrived when the question requires careful consideration by water engineers in view of the failures or partial failures that have occurred due to faulty puddle. With regard to cost, owing to the fact that the puddle core wall has to be of much greater thickness than the concrete core wall, there is no doubt that cases occur when it would also be cheaper to use concrete than puddle.

The chief feature of the aqueduct is the extensive use of tunnels, sometimes under great pressure, instead of the usual pipe syphons. Some of these tunnels are at great depths below the surface, so as to be located in solid rock, *e.g.*, the tunnel under the Hudson River, which is at a maximum depth of 1,100ft. below water level in the river, and is subjected to an internal pressure of water equal to a head of 1,500ft. of water. The use of these pressure tunnels is not novel, but it required great courage to design them so as to be called upon to bear such enormous pressures. One or two places have proved to require strengthening, but there is no doubt that, generally speaking, they have shown themselves to be very satisfactory as regards water-tightness.

A good deal of difficulty was met with at several points on account of the quantity of water which had to be dealt with in construction, and the expedient was tried of grouting the rock fissures under air pressure from boreholes driven in advance of the work. This seems to have been very successful in many cases, *e.g.*, in the incline to the Rondout pressure tunnel, where the water to be dealt with was reduced from 1,000 to 8 gallons per minute in this way. In order to deal with the water in a very wet length while concreting was going on, thin steel shields were employed, which protected the masonry during construction. These shields were placed as near the rock as possible, and the space between them and the rock was first filled with broken stone, and was afterwards grouted solid.

The author gives certain information with regard to corrosion experiments which were carried out, but does not include those experiments which had direct reference to the pipe line. The comparatively short length of the life of steel pipe lines, through which neutral or slightly acid waters are conveyed has given rise to great anxiety, and experiments were tried with the Croton water on unprotected steel, steel protected by means of Portland cement mortar, and steel in close proximity to but not actually in contact with Portland cement mortar. After two years the unprotected plate was found to be much corroded, the protected plate was in perfect condition, and the partially protected plate was only slightly corroded, showing the effect of the mortar on the thin film of water ($\frac{1}{25}$in. thick) between the steel and the mortar. It had been decided to protect the inside of the steel

pipes with Portland cement mortar, but it was felt, and it has proved to be the case that there would not be perfect adhesion of the mortar to the steel. The experiments, however, show that even under that condition the mortar will prolong the life of the steel syphon. Generally speaking, pressure tunnels were preferred to steel pipe lines owing to the fact that they are not liable to deterioration.

The author has given the various lengths of the different types of aqueduct, but it will be of interest to add the actual cost, as it averaged up to last year, per square foot of waterway per foot run, which works out as follows :—

Cut and cover	24 cents.
Grade tunnels	49 ,,
Pressure tunnels	87 ,,
Steel pipes	84 ,,

It would therefore appear as there is so little difference in cost between the pressure tunnels and the steel pipes, the former were rightly preferred on account of their longer life.

The skill with which every detail of this gigantic undertaking has been thought out is a very high testimony to the ability of the staff of engineers, and their chief Mr. Waldo Smith, and the author's paper is of great value in bringing this most important work to the notice of British engineers.

IRRIGATION IN INDIA.

By R. H. Cunningham.

[*This paper was read in November last before the Crystal Palace Engineering Society (affiliated to the Society of Engineers, Incorporated), Mr. Cunningham being at that time a student at the Crystal Palace School of Practical Engineering.*]

Mr. Charles Hawksley, in his Presidential Address to the Institution of Civil Engineers on November 5th, 1901, said: "In England the great irrigation works of India are seldom heard of, and I cannot but think that the magnitude of some . . . . is but little appreciated by many members of our own profession." The author might add, that for generations British India has been indebted far more to the labours of the Civil Engineer than to those of any other body of men, yet the newspapers hardly ever give even a small paragraph to the engineering works which are being continually carried on there.

The importance of irrigation to those living where droughts are perennial evils may be grasped when it is noted that 65 per cent. of the population of India is engaged in agriculture. The Indian Government has a magnificent record of good work well done in this direction alone, apart from other works, such as railways and roads. Millions of money have been sunk in order to avert the periodical famines that have ever been the curse of India, and these millions almost all return good dividends. The average return is 6½ per cent., which is satisfactory to the Government that laid out the money, and to the engineers who carried out the work, while the cultivators of the soil receive good returns on their rents for water.

The problems confronting the men who design irrigation works in India are extremely perplexing. All kinds of irregular conditions exist, the principal of which are the great variability of the rainfall, the character of the soil, and the nature of the crops raised, the rainfall being the most important factor.

The average rainfall over the whole of India is 42 inches in the year, and this varies by not more than 7 inches in any one year, so that the fluctuation from that point of view is not very great, but in some districts the annual rainfall is only one fourth of this amount, while in others it is more than double. In comparing localities, the extremes are represented by 5 inches in some cases and by nearly 500 inches in others. An excessive rainfall is a source of many engineering difficulties. The normal conditions for any given district are more easily anticipated and provided for than the abnormal years of drought which occur with an average frequency that varies very widely in different

parts of the Peninsula. It is always the abnormal conditions that put the irrigation works to the severest tests. Thus, in one year, the run-off of water from the catchment area serving one tank was only 1·9 per cent. of the total precipitation. In the next year, a year of heavy rainfall, it was 24·5 per cent. In another case, with a rainfall of 44·1 inches, the run-off was 5·1 per cent. The next year with a rainfall of 59·7 inches, the run-off was 36·1 per cent.

By the " run-off " or " yield " of a catchment area, is meant the total amount of water flowing from a given drainage area, generally in the form of streams fed by the rainfall. This is never the whole of such rainfall nor is the run-off at all proportional to the rainfall, but is greater when the rain is heavier, even though the total fall for the season may be deficient.

Further, the rainfall of any district cannot be regarded apart from the nature of the soils. These comprise, in some districts of India, vast alluvial tracts of yellow loam, clay and sand ; in others, the black cotton soils of the Deccan, where cotton is mostly grown ; in others, again, the crystalline and sandstone formations occur. Crops, too, differ greatly in the extent of their need of irrigation ; cotton does not ordinarily require any irrigation, and very little in years of drought. Barley needs irrigation only in a dry year, but wheat always requires a good supply of water, as does sugar cane, and rice takes most of all. It is estimated that 1,000,000 cubic feet of water are required to irrigate six or eight acres of ricefields, and a third of that quantity for wheat. Other Indian crops are millet, jute, indigo, linseed ; some of these are spring crops, others autumn, and all require suitable soils and varying amounts of irrigation.

Then, again, besides the character of the soil and crops, the natural disposition of the land determines what kind of irrigation must be adopted. There are three principal systems, viz. : Canals, Tanks and Wells.

In the vast alluvial plains traversed by the rivers that rise in the Himalayas and in the Western Ghats, canals and wells are by far the most numerous sources of distribution. All the great canal systems of India occur in these tracts, where tanks are in an insignificant minority. On the other hand, the channels of the rivers that rise in the Western Ghats and pass through the crystalline tracts of country are too deep, and their gradients too small to admit of use for irrigation in the plains beyond. Here, therefore, tanks form the principal supply, collecting and storing rainfall from the area surrounding them. These districts include nearly the whole of the Madras Presidency, the state of Mysore, half of Hyderabad, two-thirds of the Central Provinces, portions of Orissa, and some portions of Bengal, of Central India, and Rajputana.

In 1903 the Indian Irrigation Commission estimated that out of 297 million acres annually sown, the total area irrigated was 53 million acres. Of these, 19 million acres were irrigated from canals, 16 million from wells, 10 million from tanks, and the remaining 8 million from "other sources," the latter consisting of private canals, and water held up in natural depressions and in shallow artificial lakes.

The largest irrigation works occur in Northern India. The Chenab Canal irrigates the tract of land between the Chenab and Ravi Rivers of the Punjab. It is the largest and one of the most recent of Indian irrigation works. This canal was derived from the Chenab in 1889. Its discharge varies between 3,000 and 10,500 cubic feet per second. Ten years after its opening it irrigated 1,829,000 acres, and supported a population of 800,000. The Chenab Canal System cost £2,000,000; the gross revenue derived from it is about £500,000 annually; the value of crops raised on the land watered by it was in 1907 over $2\frac{1}{2}$ million pounds. The Bari Doab Canal was commenced in 1850, and now irrigates over 1 million acres. The Great Ganges Canal was opened in 1854. In 1878 it was supplemented with a second, and these two now irrigate nearly 2 million acres. The Ganges Canal has a maximum capacity of 7,000 cubic feet a second. It crosses the Solani Valley by an embankment and an aqueduct consisting of 15 arches of 50 feet span and 195 feet broad. The total length of embankment and aqueduct is $2\frac{3}{4}$ miles. A smaller system is the Godaveri Delta Canal System. A weir diverts the river Godaveri into three main canals. This system cost about £1,000,000, and it irrigates about 900,000 acres.

There are two kinds of canals, namely, inundation and perennial. Examples of inundation canals are the Chenab, the Sutlej, and the Indus Canals in the Punjab, and the Indus Canal in Sind. In this system, the water is led from rivers during their floods at a somewhat high level to the surrounding lands, the influx being sometimes regulated by sluice-gates, and ceasing directly the river falls. In this case, irrigation is intermittent, taking place only when the river is in flood, and depending for its extent on the height of the flood. The canal should start from a point where the river-bank is stable, and the flow of the river moderate, and in a central channel, so that the entrance to the canal, which should be protected from scour, may be easily maintained. The bottom of the canal is placed well above the bed of the river, so that the heavier detritus brought down may not enter the canal. The flood-waters conveyed by inundation canals are charged with fertilizing silt, which, if the flow is not checked, is eventually deposited on the land; these waters are consequently of much more value for agriculture than the clear waters discharged from reservoirs.

One of the principal aims of irrigation works, after arranging for the conveyance of the water in the most economical and efficient manner from the river to the land to be irrigated, is to prevent silt depositing in the canals, and, in the case of lands like Egypt, which depend for their fertility on the yearly layer of silt, to cause the current to carry its burden of silt on to the land. This result can only be secured by keeping out the heavier silt brought down by the river, which the weaker current of the canal could not carry along, by avoiding any checking of the current in the canal, and by laying out the canal so that the velocity of flow is as uniform as possible. Numbers of irrigation canals have to be cleared annually, at a considerable expense for excavation or dredging, from the deposit of silt which would have been valuable if spread over the irrigated lands.

The dimensions and fall of inundation canals vary considerably, those in the Punjab having lengths of 8 to 60 miles, widths at bottom of 6 to 50 feet, and falls of 1 in 4,000 to 1 in 10,000. The beds of the canals are generally from 5 to 10 feet below the flood level of the Indus. Inundation canals are specially valuable when applied to the irrigation of valleys having a poor soil on which hardly any rain falls, and drawing their supplies from silt-laden rivers fed by mountain rains and snows. Higher districts having such a system are dependent on the height of the flood, and cannot be secured from periodical droughts.

Perennial Canals.—By drawing water from rivers possessing a fairly good flow throughout the year, irrigation canals can be given a perennial discharge so as to supply arid lands with water whenever necessary, and not merely during the height of the river floods, thus enabling the districts served to be more fully cultivated, with greater certainty than by the intermittent system of inundation canals dependent on the flood rise.

Perennial canals form off-shoots from rivers, providing artificial watercourses in regions where natural ones do not exist; but instead of receiving tributaries in their course like rivers, they are eventually separated into several minor branches, which are again divided into a number of distributing branches, or channels, to spread the supply of water over the land.

Great care has to be taken in designing these canals, to adjust their cross-section and their fall, so that they may discharge the full volume of water required to irrigate the district they command, and that their current may not be rapid enough to erode their bed, or so sluggish as to favour the growth of weeds and the deposit of silt. Where the available fall is large, the channel when traversing rock may be reduced in section; but in soft soil it becomes necessary to introduce vertical falls at suitable points to avoid creating an undue current, as adopted on the Ganges Canal.

There are two types of perennial canals, namely: upper perennial, or those which draw their supplies from rivers in the higher part of their course, and convey the water to the lower parts of their valleys over long distances, with the good fall generally available, away from the course of the rivers; and, secondly, deltaic perennial, or those which start from a deltaic river at the head of its delta, and irrigate the low lands lying between the diverging branches of the delta.

Upper Perennial Canals.—The works for these canals consist, firstly, of the main canal conveying the water from the upper part of a river to the district to be irrigated, together with its branches and minor channels for distribution in this district, and, secondly, the headworks at the intake of the canal, comprising a weir across the river a little below the entrance of the canal, to raise the water in the river during its low stage in front of the intake, and regulating sluice-gates across the intake to control the influx into the canal, and to exclude the high floods passing down the river, which, if admitted into the canal, would injure and might break its banks, and introduce large quantities of silt which would be deposited in the canal as the initial velocity of influx decreased.

The works for the main canal resemble those for forming the channel of a navigation canal, with the exception that the bed of the canal must be given a fall to provide for the flow of its waters. In cuttings through porous strata, and on embankments, the trough for the canal has to be made watertight by a lining of clay, concrete, or other impermeable material. High embankments are avoided, if possible, and the greatest care is taken in forming the embankments to guard against settlement or slips, which would be attended by serious damage. Aqueducts carrying canals over rivers or roads, differ from railway viaducts in having to provide a watertight trough, (with a towing path at the side if required for navigation) and in being subjected merely to the dead load of the aqueduct and the water carried by it, and not to any moving or live load.

The weir may be constructed with masonry or rubble stone, protected in the latter case by masonry or pitching on the top. As a solid weir across a river bringing down detritus causes an accumulation of deposit in the river-bed above the weir, which would be liable to block up the entrance to the canal, sluice openings are formed through the weir near the bank, closed by draw-doors, the scour through which when opened keeps the river-bed in front of the entrance to the canal free from deposit.

At the headworks of the Chenab Canal the river is about $3\frac{1}{2}$ miles broad (broader than is necessary for the discharge of the floods). The weir holds up the water as much as 12 feet above low-water level. The weir itself is only 4,000 feet long, but over

it the whole discharge is compelled to pass by a system of training walls. Forty feet upstream of this wall a masonry curtain wall has been sunk 20 feet into the bed, to prevent undermining. The weir is divided into eight equal bays by masonry piers. Between the piers, on the crest of the weir, are rows of vertical iron shutters, the construction and action of which may be taken as typical of all those now generally employed on Indian weirs. The shutters, 6 feet high and 3 feet broad, are made of $\frac{3}{16}$ inch steel plating stiffened with angle iron. Heavy double hinge blocks placed between two adjacent gates are bolted down to the masonry. Three feet upstream of each shutter a tie-rod is hinged to the crest of the weir; its other end slides in a groove on the nearer face of the gate, and is fitted with a hook which falls automatically into a slot when the gate is erect and is caught by a trigger. To let the shutter fall, this trigger is knocked to one side, and the shutter is laid flat by the pressure of the water behind. The shutters are controlled by hydraulic brakes, which allow them to fall slowly.

Deltaic Perennial Canals.—The width of a river near its delta is generally considerable, which necessitates a long weir across the head of the delta. The weirs across the Godaveri and Mahanadi deltas are $2\frac{1}{2}$ and $1\frac{1}{4}$ miles long respectively. The regulating sluices are similar to those constructed for upper perennial canals; and the canals themselves present no difficulty in construction, being formed throughout in flat land. Owing to the small fall available, these canals are not liable to be eroded by the current; but with the small velocity of their flow, they are subject to accumulations of silt.

Escapes or Wasteways.—In order to maintain complete control over the water in a canal, provision is made for the disposal of any excess flow that may arise from sudden and excessive floods, or of any water not required for irrigation. This is effected by means of escapes or wasteways. These are usually short cuts from the canal to some natural drainage channel or stream into which the excessive water may be wasted without fear of damage. On most Indian canals there are facilities for letting off surplus water, but in the case of the Chenab Canal the main courses are so far from the rivers that the provision of escapes back into rivers at the points where they are needed, is, in most cases, impossible. As an alternative, several natural depressions in the ground have been surrounded with earthern banks to form reservoirs, into which a portion of the discharge can be turned in an emergency. The water in them soon dries up, and leaves them free for further use.

Tanks.—The storage tanks of India are very numerous, ten million acres being irrigated from them. There are more than 33,000 tanks in the Madras Presidency, and 40,000 in

Mysore, that is about three or four per square mile. These tanks are a source of anxiety, because if a flood happens to burst one, others in the vicinity will be swept away. There is in Mysore a dam, across a valley 142 feet high, enclosing a basin 2,075 square miles in area, containing, if it were filled (which would not often occur) 30,000,000,000 cubic feet. Yet this is only a "tank" according to Indian reckoning.

A large portion of the irrigation of Southern India is effected by tanks that are local works, distinct from the great Government schemes, and some of them are works of great antiquity. To mention a few; the tanks at Chingleput are 1,100 years old, and still irrigate 6,000 acres. The Grand Anicut Dam, the construction of which is ascribed by tradition to the close of the second century, was in use until 1830. It was over 1,000 feet in length, from 40 to 60 feet in breadth, and 15 to 18 feet in depth, and its waters irrigated 670,000 acres. Ruins of ancient irrigation works many centuries old, sometimes overgrown with jungle, exist in various parts of India. The "Giant's Tank" was built in the fifth century. In the Madras Presidency, before it came under British rule, there were 50,000 tanks, large and small, and 30,000 miles of embankments.

Tanks are readily formed by enclosing a natural depression with an earthwork embankment, in which rainfall is collected; or, sometimes, a series of these embankments, placed across a valley at intervals, draws the flow of rain water off the ground from a larger area, forming a succession of small reservoirs. The water thus stored up in the rainy season is drawn off for irrigation in the dry season, through one or more sluices or outlets built in masonry in the embankment; and a waste weir, or an escape side channel is provided for the discharge of surplus water, to secure the embankment from being overtopped by the water, which would result in a breach, and the loss of the contents of the tank.

More individually important, but really in the same class as tanks, are the reservoir systems, which occur chiefly in the Bombay Presidency. Large volumes of water can be stored up for irrigation by erecting a masonry dam across the lower part of the valley of a small river, arresting the flow of water during floods till the water has filled the reservoir space above the dam, the volume of water thus stored up depending upon the height of the dam and the configuration of the valley above. A narrow part of the valley is generally selected, which widens out considerably higher up, so that a comparatively short dam across a gorge retains a large volume of water, and wasteways are provided for the outlet of surplus water.

The most interesting of reservoir systems is that emanating from the Periyar River, which flows down the Western slope of the

Western Ghats to the Indian Ocean. The greater portion of the rainfall on the Western Ghats flows into the Indian Ocean, leaving the country to the East in a parched condition, were it not for the irrigation works. The Periyar system taps the river, stores its water in a reservoir on the Western side of the Ghats, and leads it through a tunnel for distribution in the Madura district.

The most imposing piece of work of this undertaking is the dam built across the Periyar river. Its thickness at the base is 139 feet, and 12 feet at the top, it is 1,241 feet long and 178 feet in height, and is built across a river having an average discharge of 1,200 cubic feet per second, rising in floods to 25,000 cubic feet per second. The construction of the dam with its foundations required 5 million cubic feet of concrete, composed of 100 parts of broken stone, 30 parts of sand, and 25 parts of hydraulic cement, besides stone for facings. Owing to the unhealthy conditions which existed during three months of the year and the floods prevailing during a further six months, only three months in each year were available for filling in foundations.

The tunnel through the ridge between the Periyar and the Vaigai is 5,600 feet long, and the discharge through it might amount to 1,800 cubic feet a second. It is 12 feet wide by 7½ feet high, and is bored through solid syenite rock. The area of the artificial lake impounded varies with the height of the water. It has a normal level and an escape level, the latter being to give passage to surplus water during heavy floods. It is 31 feet above the normal level. The lake has an area of 3,765 acres at normal level and 7,454 acres at flood level, the depths being 131 feet and 162 feet respectively. At escape level the contents are 13,299 million cubic feet, and 6,815 million cubic feet are available for irrigation. This portion is drawn off through the tunnel and led down the river Vaigai for a distance of 86 miles to the Madura district, where 180,000 acres are irrigated. The two most important of the many reservoirs in the Bombay Presidency, are Lake Whiting and Lake Fife.

Closure of the Dam.—This portion of the work gives the engineer the greatest anxiety, as a temporary passage for an immense quantity of water has to be provided until the beginning of the next working season, when the last gap has to be closed within a few months. During all the working period of the final closure, a very large body of labourers must be kept constantly at work.

The ordinary method of closure is shown in sketch (Fig. 1). The shaded portions are first constructed, leaving a narrow gap in the river-bed for the passage of the monsoon discharge. The central gap has then to be completed during the last season of work. The objections to this method are :—

(1) The junction between the two parts is too high. One part, being made at least one season before the other, and having been allowed to settle in the open, at the time of junction has practically attained its final consolidation, whereas the other part is quite green. The two cannot properly unite, and there is always a risk of a leak at the junction.

(2) The final closure, while quite green, is at once subjected to the infiltration due to a full reservoir; the water thus entering it prevents it from attaining the density of the first part for many years.

(3) The final closure having to be completed in one season, the work is, to an undesirable extent, in the hands of the labourers, and strikes and higher rates are probable.

This method of closure can be adopted without much risk in the case of dams less than 30 feet high.

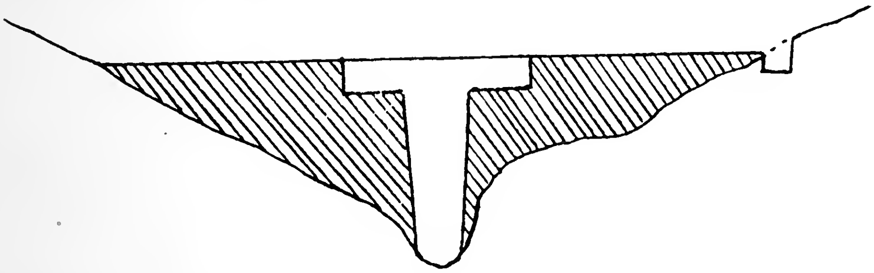


FIG. 1.

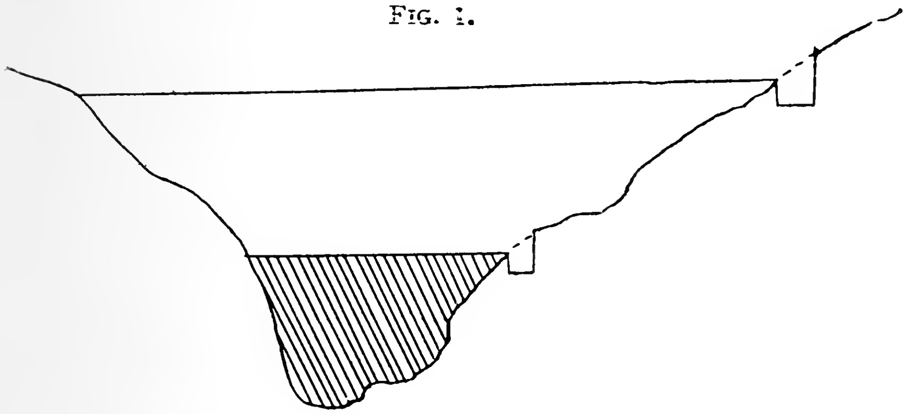


FIG. 2.

An improved method of closure, shown in Fig. 2, consists in forming the dam in continuous level stages, commencing at its lowest point, and gradually working up to its final crest. To provide for the escape of flood water during construction, a temporary waste weir is made to discharge the maximum flood with safety to the whole work. This system is a safe one to adopt for dams of greater height than 30 feet.

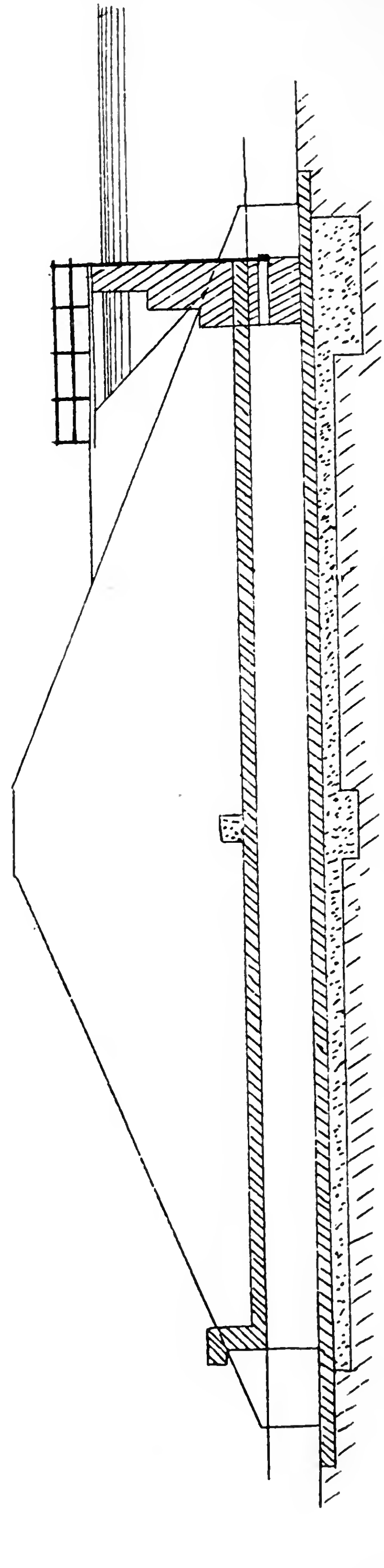


Fig. 3. Culvert under Dam.

Its advantages are :—

(1) The junction is very much less in height than in the first case.

(2) The first closure is subject only to infiltration from a low reservoir.

(3) The bulk of the dam, and, in particular, its highest sections, can be carried up slowly and evenly and allowed to consolidate. Only the small portion closing the temporary waste-weir will have to be done in one season.

(4) The work can be done without fear of strikes, as the final closure involves a comparatively small amount of construction.

(5) The construction of the first closure will lead to the formation of a small reservoir which will be most useful for works purposes.

The Outlet.—The outlet is the work by means of which the water contained in the reservoir is passed safely through, or round the dam, so that it may be utilised for the purposes for which the storage has been effected. In the smallest native tanks the outlet is simply a cut through the bank, which is opened when water is required for irrigation, and is closed by embankment when the supply is no longer needed. Four kinds of outlet are shown in Figs. 3 to 6.

Culvert under the dam (Fig. 3).—This form of outlet is usually the cheapest, and, when properly constructed, can be made perfectly safe. It cannot be properly inspected or repaired when necessary, as it is under a large mass of made earth, but as the whole of the construction of the work is executed in the open, there should not be any difficulty in securing first-rate workmanship.

RESERVOIR.

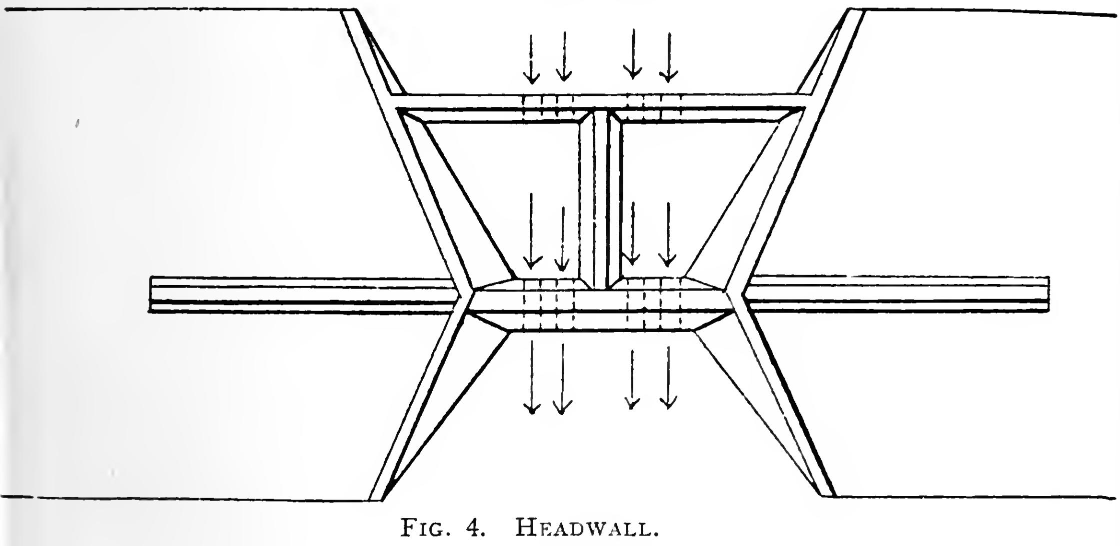


FIG. 4. HEADWALL.

Headwall in the centre line of the dam (Fig. 4.).—This outlet may be described as a short length of a masonry dam inserted in an earthen one (the two being united by long staunching walls, one at each side), a passage being kept open for the discharge of the water by means of four wing walls. The headwall is pierced by outlet culverts, controlled at their upstream face by valves. The work, being wholly open, can be easily constructed, inspected and repaired. The reservoir can be kept low during the early part of the monsoon, when the floods are most silt-laden, and excessive silt deposit can be thus prevented.

Outlet Tower in the centre line of the dam (Fig. 5.).—This is known in America as the "dry well." A culvert is constructed under the dam, and where it crosses the core wall, a rectangular tower is built up as the dam is raised, and in it are placed the valves controlling the discharge. The core wall is

RESERVOIR.

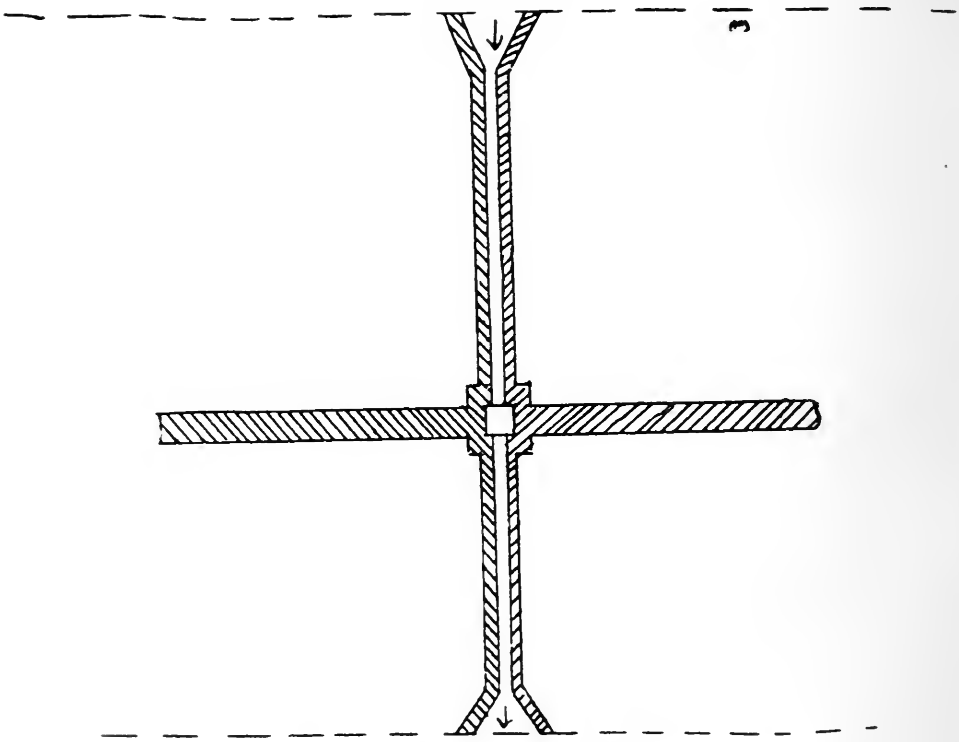


FIG. 5. DRY WELL.

built in the dam along its centre line to minimize the risk of infiltration. It may be constructed of masonry or concrete, or of puddle clay, and should go down to the foundations of the dam. Care is necessary when making a "dry well" in the dam; but given this condition, the joining of the core wall and outlet can be satisfactorily effected.

RESERVOIR.

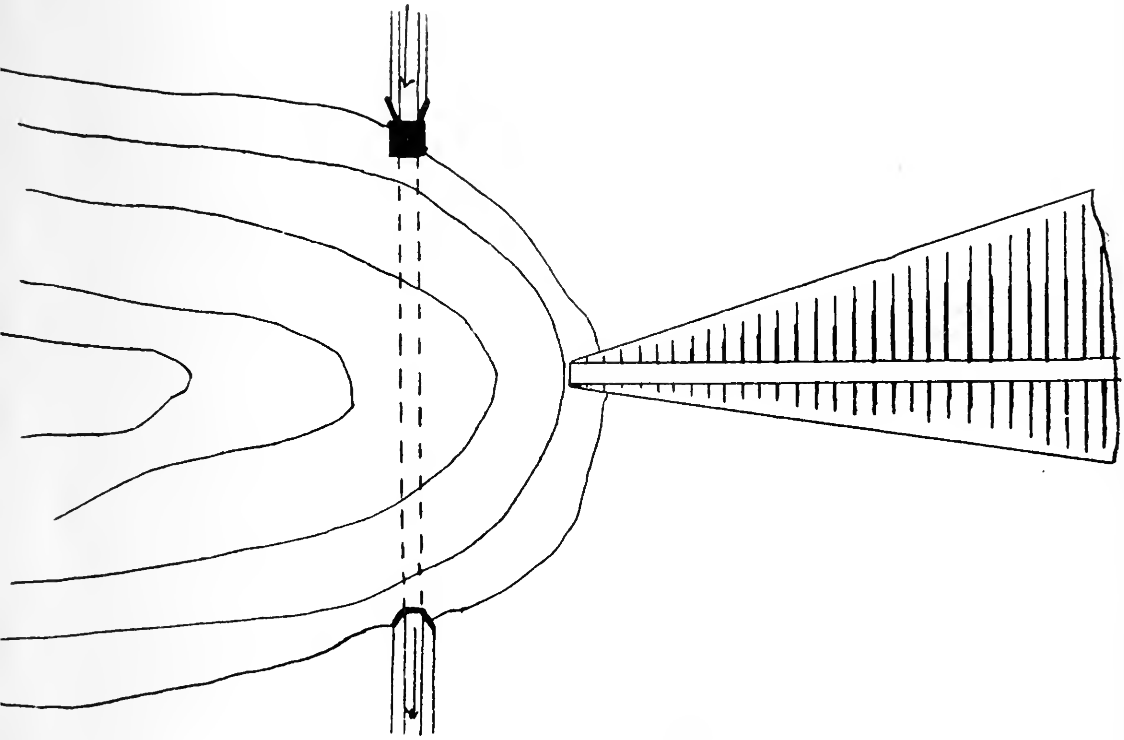


FIG. 6. TUNNEL OUTLET.

Tunnel round the dam (Fig. 6.).—This form of outlet being quite independent of the dam, cannot in any way affect it ; it is, therefore, a very safe one to adopt. The disadvantage of this type is its great expense, which is unnecessary, seeing that some other form of outlet can generally be adopted without risk.

Revenue from Tanks.—If an irrigation work pays a little more than its working expenses during normal periods, it may, from this point of view, be accepted as a scheme financially sound in regard to the country as a whole, although far from being a directly remunerative one to Government. It is useless to expect from tank irrigation the good returns derived from large canals supplied by the great perennial rivers, which do not require expensive storage works. It must be remembered that tank schemes are the only ones available for the lands they serve, and that it is the duty of the Government to develop the country so far as their finances will permit. If expenditure on relief during times of famine is devoted to the construction of such works, instead of being incurred on works of only temporary utility, each successive famine will thus permanently enrich the country and render it better able to withstand the effects of future scarcity.

Wells.—Well water is a means of irrigation dating from very remote times. There are in India 16 million acres of irrigation by 3½ million wells, the lifting being done by cattle. The Irrigation Commission reported that there was room for another 16 million acres of irrigation by wells in India. In the alluvial plains of Northern India 9½ million acres are irrigated out of a total of 13 millions irrigated from 2½ million wells in British territory. In the Punjab, where the subsoil contains an inexhaustible supply of water, each well irrigates, on an average, 11 acres. Among the primitive methods of irrigation from wells is this ; a bag of cowhide or leather is lowered into a well, a rope attached to the bag is passed over a pulley, and bullocks haul up the bag of water by running down a hill. The water is emptied into a trough at the top of the well and is distributed over the fields by gravitation.

There are places in India where water could be pumped from wells or rivers at comparatively small cost, but the use of pumps seems to be restricted to Madras. Pumps are widely used in America for purposes of irrigation and their use is increasing.

Reference may also be made here to the Shuman-Boys Sun Heat Absorber installed at Meadi, Egypt, in which solar energy is utilized to raise steam for pumping water from the Nile. The water thus raised is then distributed to the adjacent land for irrigation purposes.*

Works now under Construction.—A vast irrigation scheme in the Punjab employs 8,000 natives, superintended by only four Europeans. This scheme will irrigate 2,000,000 acres and attract a large population to what is at present an uncultivated waste. It involves the construction of three canals, the Upper Jhelum, the Upper Chenab, and the Lower Bari Doab Canals. This last named will be 200 feet wide and 10 feet deep, and will be carried across the Ravi River, which in flood time has a width varying between one and three miles. Another part of the scheme is a barrage, 1,650 feet long, across the river Ravi.

Another large work now in progress lies in the Upper Swat Valley. This is supplementary to work begun more than 30 years ago in the lower part of the valley. A feature of this work is a tunnel through granite rock. It will be 11,226 feet long, 18 feet wide, and 12 feet high. The water of the Swat River drives turbines and electrical machinery for drilling the rock which is so hard that four hundred drills have to be ground daily. In the official returns of 1911, it is stated that there are 1,326 miles of main State Canals in course of construction, and 4,939 miles

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* This plant is fully described and illustrated in a paper on *The Utilisation of Solar Energy*, read before the Society by A. S. E. Ackermann, B.Sc. (Engineering) on April 6th, 1914. See page 81 of this volume.

of distributing canals, by far the greater proportion being in the schemes just mentioned.

As regards the effects of the irrigation works upon the social life of the people of India, it may be mentioned that the Swat River Canal, which lies in a district on the borders of the Punjab, formerly the home of very turbulent tribes, did more in ten years to induce the people to settle quietly in the villages than could have been done by the police of the Province in a much longer time.

About fifty years ago, in the terrible famine of Orissa, a million persons, or one-fourth of the total population of the Province, died of starvation, notwithstanding that 1½ million pounds had been expended on relief works. In 1877-78 the death-rate through famine in India was 5¼ millions over that in normal years, while the birth-rate was less by 2 millions. During the years 1873-78 the money spent on relief works amounted to 16½ million pounds.

India is now enjoying a vastly larger share of prosperity and immunity from starvation than she has ever known under even the best of her native rulers. This is due to the great State irrigation works carried out, on which £38,000,000 has been spent, and they have rendered productive many millions of acres. It is not a question of making two blades of corn grow where but one grew before, but of growing corn, and rice, and sugar, where, without irrigation, the land would be a desert.

The rulers of India see in the great irrigation works, not only a sound investment, but, what is more important by far, a political force and a powerful and beneficent means of convincing the agricultural population—by far the most numerous and important in the country—that Britain rules India primarily and emphatically for the good of the races that dwell there.

THE DYNAMIC INCREMENT OF A UNIFORMLY DISTRIBUTED LOAD.

By Prof. HERBERT CHATLEY, B.Sc. (Eng^{g}), M.I.C.E.I.

The dynamic increment of a single concentrated rolling load on a uniform beam supported at both ends, the load advancing with a constant velocity, has been discussed by the present writer elsewhere. It was shewn that the increment would not ordinarily exceed

$$\frac{2\, W^2 V^2 L}{3\, g\, E\, I}$$

When the load is a distributed one the conditions are much more complex. If d^2y/dx^2 is the vertical acceleration (downwards) of any point situated at a distance x from the left support (covered by the advancing load), then the loading in a small length dx is

$$w\cdot dx\left(1-\frac{w\cdot dx}{g}\cdot\frac{d^2y}{dt^2}\right) \text{ .... } (1)$$

Since $\dfrac{d^2y}{dt^2}=V^2\cdot\dfrac{d^2y}{dx^2}$ and y (the deflection) is a function of x,

it appears that the effect of the dynamic increment is to make the load non-uniform. If we neglect the "compound interest" effect, *i.e.*, take the vertical acceleration as if it were not affected by the dynamic increment, the problem resolves itself into the question of finding the vertical accelerations of the load as functions of x.

When the front of the advancing load is x from the left support, the reactions are

$$R_1=\frac{wx\left(L-\dfrac{x}{2}\right)}{L}$$

$$R_2=\frac{wx^2}{2L} \text{ .... } (2)$$

at the right and left supports respectively.

The bending moment at any point X from the left support is (between O and X) :—

$$M_{x_1}=\frac{wx\left(L-\dfrac{x}{2}\right)x}{L}-\frac{wx^2}{2}$$

between X and L_1

$$M_{x_2} = \frac{wx\left(L - \frac{x}{2}\right)x}{L} - wx\left(x - \frac{x}{2}\right) \quad \ldots\ldots (3)$$

The deflection of the *beam* at a point $\frac{x}{2}$ from the left support, *i.e.*, under the centre of gravity of the load, is

$$\frac{w}{4EI}\left[\frac{x^3L}{3} + \frac{19x^4}{32} - \frac{11x^5}{8L} + \frac{x^6}{2L^2}\right]$$

$$= \frac{w}{EI}\left[0 \cdot 08\dot{3}x^3L + 0 \cdot 14838x^4 - 0 \cdot 3438x^5L^{-1} + 0 \cdot 125x^6L^{-2}\right]$$

$$\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

The deflection of the beam at the centre when the load wholly covers the beam ($i.e.$, $x = L$) is

$$\frac{5}{384}\frac{wL^4}{EI} = 0 \cdot 01302\,\frac{wL^4}{EI}$$

The load is however *not straight*, but (supposing it to be flexible, as is usually the case) curved with the beam, and the c.g. of the load sinks, when at the centre, only to a level of

$$\frac{wL^4}{240\ EI} = 0 \cdot 00417\,\frac{wL^4}{EI}$$

This value, and others for other positions of the load, can be obtained in two ways :—

(1) By considering the position of the *c.g.* of a flexible load curved to the shape of the beam, or

(2) By computing the strain energy accompanying the flexure and considering it as the product of half the load on the beam into the deflection of the centre of gravity.

The *mean value of the dynamic increment* for any position of the load is equal to the product of the mass of the load on the beam into the *mean* vertical acceleration of the load. The mean vertical acceleration of the load is equal to the vertical acceleration of the centre of gravity of the load on the beam.

The vertical acceleration of the *central point* of the load is easily found (neglecting the compound interest effect) by differentiating (4) twice with respect to x and multiplying by the square of the velocity of the load as follows :—

$$\frac{d^2y}{dt^2} = \frac{wV^2}{EI}\left[0 \cdot 5xL + 1 \cdot 78062x^2 - 6 \cdot 875x^3L^{-1} + 3 \cdot 75x^4L^{-2}\right]$$

(See Table I. p. 228) downwards........................ (5)

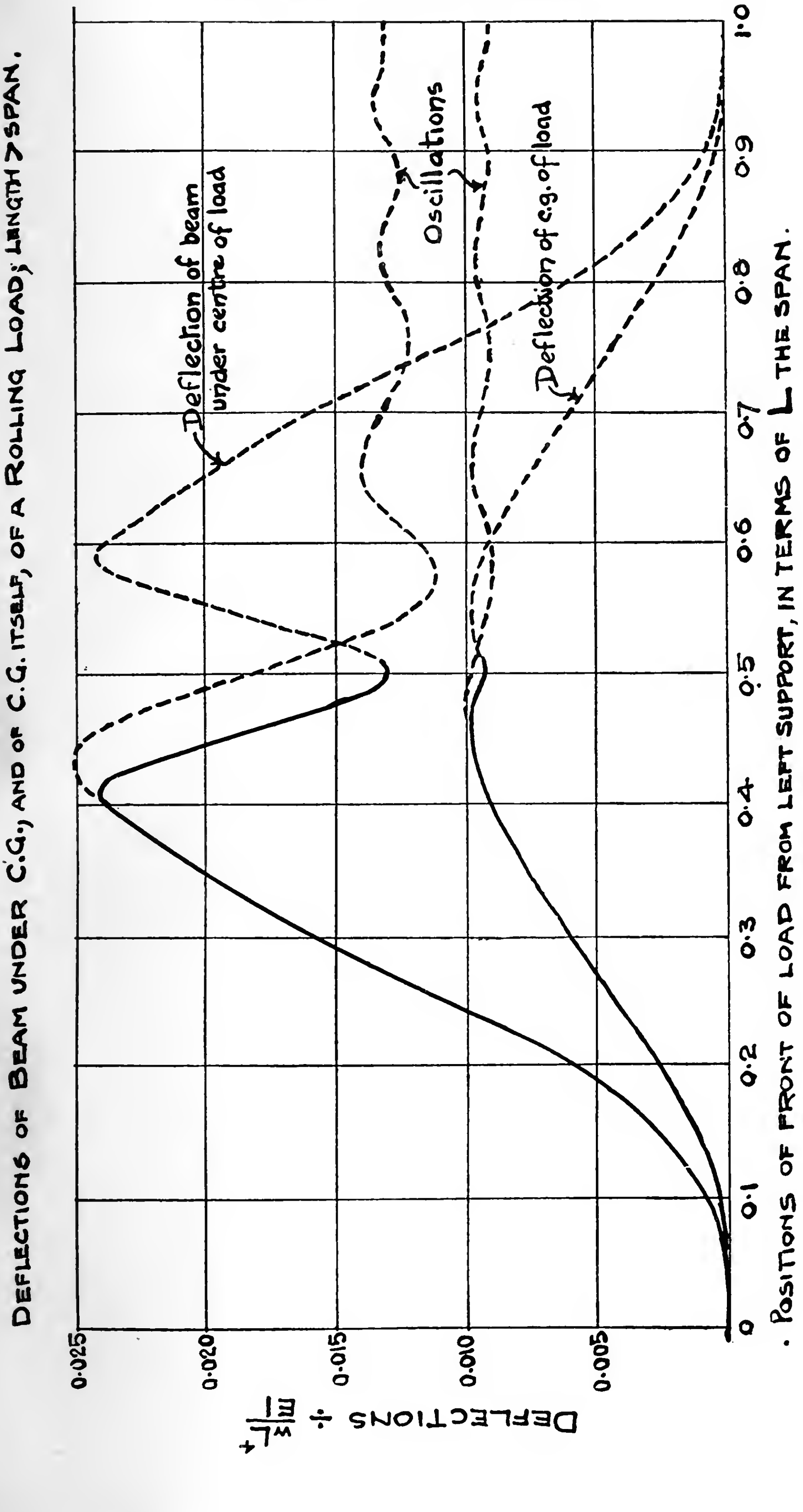
DEFLECTIONS OF BEAM UNDER C.G., AND OF C.G. ITSELF, OF A ROLLING LOAD; LENGTH > SPAN.
DEFLECTIONS ÷ $\frac{wL^4}{EI}$
0·025
0·020
0·015
0·010
0·005
0
0·1
0·2
0·3
0·4
0·5
0·6
0·7
0·8
0·9
1·0
Deflection of beam under centre of load
Oscillations
Deflection of c.g. of load
POSITIONS OF FRONT OF LOAD FROM LEFT SUPPORT, IN TERMS OF L THE SPAN.

Fig. 1.

The vertical acceleration of the *centre of gravity* is less than this, and may be found by treating the deflection of the centre of gravity in the same way.

If U_x = the flexural resilience when the front of the load is at x from the left support, then

$$U_x = \tfrac{1}{2}\left(wx\right) \cdot \triangle$$

where $\triangle$ is the deflection of the centre of gravity, so that

$$\triangle = \frac{2U_x}{wx} \qquad \text{.................................... (6)}$$

and the dynamic increment for all of the load on the beam is

$$\delta F = -\frac{wx}{g} \cdot \frac{d^2\triangle}{dt^2} = -\frac{wx}{g} \cdot V^2 \cdot \frac{d^2\triangle}{dx^2} \qquad \text{...........(7)}$$

$$U_x = \frac{1}{2EI}\left\{\int_0^X M_{x_1}^2 \cdot dx + \int_X^L M_{x_2}^2 \cdot dx\right\}$$

$$\int_0^X M_{x_1}^2 \cdot dx = w^2\left[\left(x^2 - \frac{x^3}{L} + \frac{x^4}{4L^2}\right)\frac{x^3}{3} - \left(x - \frac{x^2}{2L}\right)\frac{x^4}{4} + \frac{x^5}{20}\right].$$

$$\int_X^L M_{x_2}^2 \cdot dx = \frac{w^2 x^4 (L-x)^3}{12L^2}$$

$$U_x = \frac{w^2}{24EI}\left[x^4 L - 1 \cdot 4x^5 + 0 \cdot 5x^6 L^{-1}\right] \text{...........(8)}$$

$$\triangle = \frac{w}{12EI}\left[x^3 L - 1 \cdot 4x^4 + 0 \cdot 5x^5 L^{-1}\right] \text{...........(9)}$$

The velocity and acceleration (downwards) are

$$\frac{d\triangle}{dt} = V \cdot \frac{d\triangle}{dx} = \frac{w \cdot V}{12EI}\left[3x^2L - 5 \cdot 6x^3 + 2 \cdot 5x^4L^{-1}\right] \text{..... ......(10)}$$

$$\frac{d^2\triangle}{dt^2} = V^2 \cdot \frac{d^2\triangle}{dx^2} = \frac{wV^2}{12EI}\left[6xL - 16 \cdot 8x^2 + 10x^3L^{-1}\right] \text{...........(11)}$$

(See Table II. page 228.)

The vertical *upward* acceleration (which *increases* the load) is a maximum near the centre (about $0 \cdot 9$ of *half* the span). The *mean* dynamic increment for unit span is then

$$0 \cdot 077\,\frac{w^2}{g} \cdot \frac{L^2V^2}{EI} \quad \text{or} \quad 0 \cdot 069\,\frac{w^2L^3V^2}{gEI}$$

for the whole load on the beam $(0\cdot 9\,wL)$

When the c.g. is at the centre (beam wholly covered), the mean increment is $0\cdot 066\,\frac{w^2L^2V^2}{gEI}$ for unit span, or $0\cdot 066\,\frac{w^2L^3V^2}{gEI} = 0\cdot 066\,\frac{W^2LV^2}{gEI}$ for the whole span, where W is the whole load $(= wL)$. (Compare this with the expression $\frac{2W^2V^2L}{3\,gEI}$ given at the beginning of this paper for a single concentrated load W). Thus the mean dynamic increment for a distributed load appears to be only about one-fifth* that of an equal concentrated load.

To allow for the compound interest effect, using the approximation $(1+a)^2 = 1 + 2a$, the coefficient should be doubled, making the final expression for the mean dynamic increment

$$\delta F = \frac{0\cdot 133\,w^2L^2V^2}{gEI} \quad \text{per unit span, or}$$

$$\frac{0\cdot 133\,w^2L^3V^2}{gEI} \quad \text{for the whole span...... (12)}$$

The vertical acceleration of the *central* parts of the load when the beam is wholly covered is

$$\frac{0\cdot 844\,w^2L^2V^2}{gEI} \quad \text{per unit span.}$$

The absolute maximum dynamic increment for any part of the load would then appear to be (doubled for compound interest effect)

$$\frac{1\cdot 7\,w^2L^2V^2}{gEI} \quad \text{per unit span.}$$

The diagrams show how the deflection under the centre of gravity, and the deflection of the centre of gravity change with the advance of the load, and also the vertical velocities and accelerations incidental thereto. The subsequent oscillations are also indicated roughly.

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* The $\frac{2}{3}$ coefficient is twice $\frac{1}{3}$, being doubled for the compound interest effect.

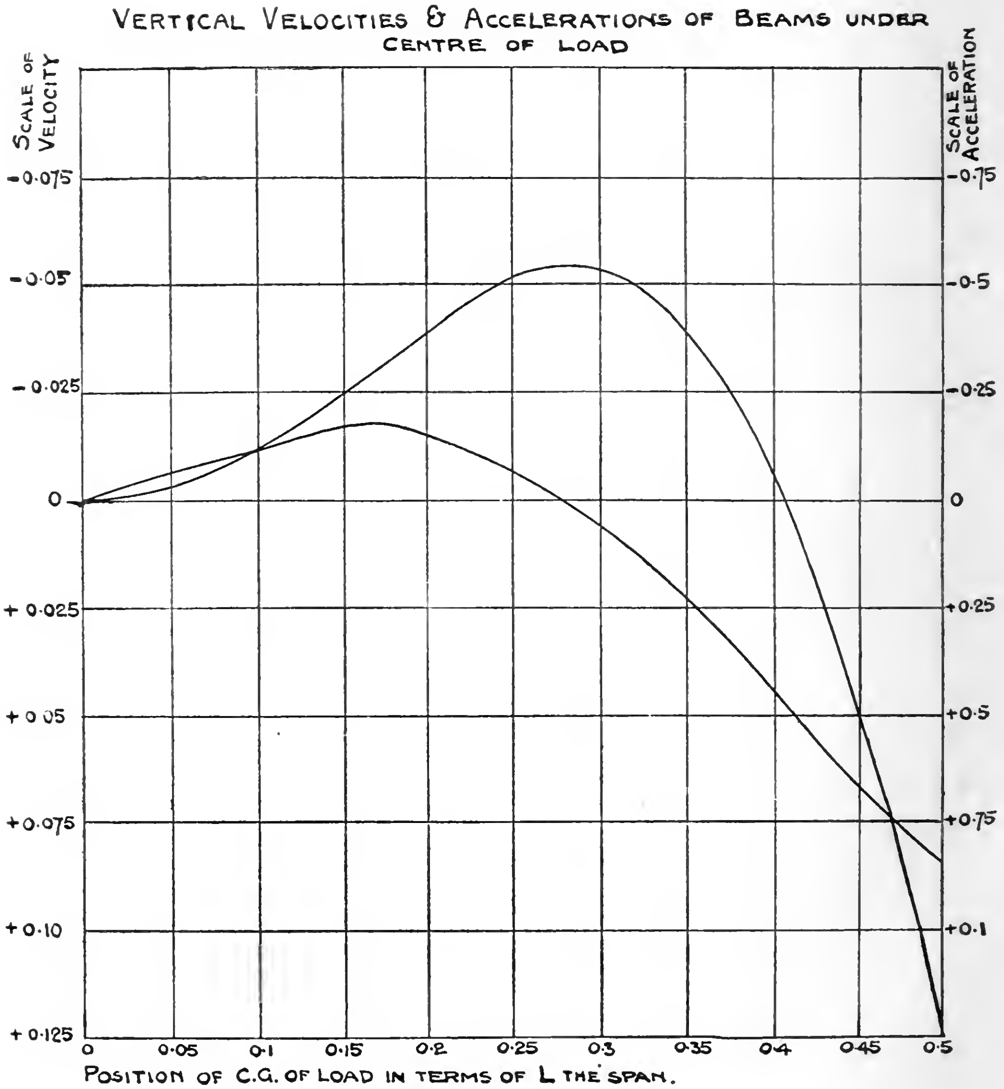

VERTICAL VELOCITIES & ACCELERATIONS OF BEAMS UNDER CENTRE OF LOAD
SCALE OF VELOCITY
SCALE OF ACCELERATION
-0·075
-0·05
-0·025
0
+0·025
+0·05
+0·075
+0·10
+0·125
-0·75
-0·5
-0·25
0
+0·25
+0·5
+0·75
+0·1
0
0·05
0·1
0·15
0·2
0·25
0·3
0·35
0·4
0·45
0·5
POSITION OF C.G. OF LOAD IN TERMS OF L THE SPAN.

FIG. 2

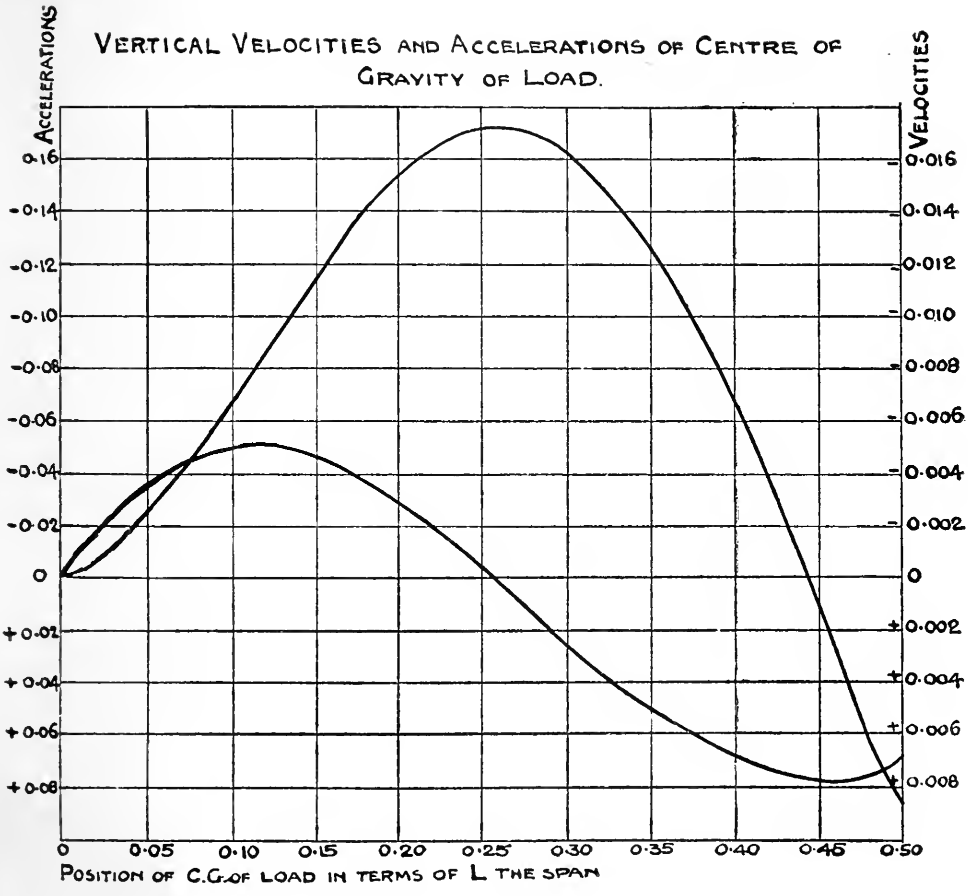

VERTICAL VELOCITIES AND ACCELERATIONS OF CENTRE OF GRAVITY OF LOAD.
ACCELERATIONS
VELOCITIES
0.16
-0.14
-0.12
-0.10
-0.08
-0.06
-0.04
-0.02
0
+0.02
+0.04
+0.06
+0.08
0.016
0.014
0.012
0.010
0.008
0.006
0.004
0.002
0
+0.002
+0.004
+0.006
+0.008
0
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.50
POSITION OF C.G. OF LOAD IN TERMS OF L THE SPAN

FIG. 3.

TABLE I.

Position of Front of Load from left Support in terms of L.	Position of Centre of Gravity of Load in terms of L.	Deflection of Beam under Centre of Gravity in ins.	Vertical Velocity of Beam at same place in f.s.*	Vertical Acceleration of Beam at same place in f.s.s.
0	0	0	0	0
0·1	0·05	$-0\cdot0001\ \frac{wL^4}{EI}$	$-0\cdot0032\frac{wL^3V}{EI}$	$-0\cdot0613\frac{wL^2V^2}{EI}$
0·2	0·10	−0·0009	−0·0123	−0·1222
0·3	0·15	−0·0026	−0·0248	−0·1743
0·4	0·20	−0·0061	−0·0417	−0·1408
0·5	0·25	−0·0109	−0·0515	−0·0702
0·6	0·30	−0·0159	−0·0538	+0·059
0·7	0·35	−0·0200	−0·0395	+0·228
0·8	0·40	−0·0237	−0·0061	+0·445
0·9	0·45	−0·0195	+0·049	+0·662
1·0	0·50	−0·0130	+0·1252	+0·844

*A minus sign indicates a downward velocity.

TABLE II.

Position of Centre of Gravity of Load in terms of L.	Deflection of Centre of Gravity in ins.	Vertical Velocity of c.g. in f.s.	Vertical Acceleration of c.g. in f.s.s.
0	0	0	0
0·05	$-0\cdot000072\ \frac{wL^4}{EI}$	$-0\cdot00247\ \frac{wL^3V}{EI}$	$-0\cdot0368\ \frac{wL^2V^2}{EI}$
0·10	−0·000493	−0·0066	−0·0506
0·15	−0·0012416	−0·01159	−0·0465
0·20	−0·002756	−0·01546	−0·0293
0·25	−0·004426	−0·01719	−0·0042
0·30	−0·00612	−0·0162	+0·024
0·35	−0·00757	−0·0124	+0·0502
0·40	−0·00853	−0·0064	+0·0693
0·45	−0·00890	+0·00101	+0·0765
0·50	$-0\cdot008\dot{3}$	$+0\cdot008\dot{3}$	$+0\cdot0\dot{6}$

TRADE UNIONISM AS APPLIED TO PROFESSIONS.

The following is an abstract of a paper under the above title, by A. B. Howes, LL.B., Barrister-at-Law, read before the Quantity Surveyors' Association (Incorporated) on April 23rd, 1913. As the paper is of considerable interest and importance, permission has been obtained from the Author and the Association for its publication in an abbreviated form.

In the history of commerce, trade, and manufacture, the advantage of dividing labour into distinct branches was realized at an early period, and as civilization progressed the adoption of this principle became one of its distinguishing features, and in many ways tended to its advancement. Division of labour in general means the employment of an individual upon one kind of labour, and this circumstance forms one of the chief differences between uncivilized and civilized nations.

As trades became separate we find an increasing tendency for their members to unite. Under the Roman Law there were many such corporations, which could not be created by private agreement, but required the authority of a statute (*Senatus consultum*) or ordinance of an Emperor. The internal government of such corporate bodies was, however, in the hands of the members.

Our own mediæval guilds were of two kinds, the "guild-merchant" and the "craft guild." The former was the older institution, and was a voluntary association formed among merchants for the mutual aid, benefit, and protection of its members, brought into existence by a royal grant of *gilda mercatoria*.

The "craft guilds" usually comprised all the artizans in a single branch of industry in a particular town, their object being the mutual protection of the workers, and the making of regulations for the trade in the interest of the workers. In the 15th and 16th centuries such a fraternity was commonly called a "mystery" or "company."

A trade union at the present time is a combination for regulating the relations between workmen and masters, workmen and workmen, or masters and masters, or for imposing restrictive conditions in regard to the conduct of any industry or business.

By the Common Law such combinations were, with certain exceptions, illegal. They were considered to be contrary to

public policy, and were treated as conspiracies in restraint of trade. This view has been altered by various Acts of Parliament, and the Trades Disputes Act, of 1906, in effect placed trades unions above the law.

Turning now to Trade Unionism as applied to professions, although it is rather a contradictory use of the phrase, we find that the Medical profession appears to have been the first to receive statutory recognition, in 1461, when the Barbers of London, who then practised surgery, obtained a charter of incorporation from King Edward IV. At this time there were three main branches of the profession—physicians, barber chirurgeons, and apothecaries.

In 1518 the physicians obtained a charter of incorporation, and in that year the Royal College of Physicians of London was founded. At this time there were many surgeons practising as well as the barbers, and in 1540 they and the barbers were incorporated and were given the exclusive right to practise surgery within the City of London and its suburbs.

Further powers were obtained in 1629 by the barbers and surgeons, including the right to examine and approve all persons who wished to practise surgery. In the reign of George II. the rights of the surgeons were transferred to the Company of the Art and Science of Surgeons in London.

The Royal College of Surgeons is now a distinct body from the Royal College of Physicians, although most practitioners belong to both; in fact, with the exception of the License from the Society of Apothecaries, the minimum qualifications necessary to entitle a medical man to be registered are that he shall be a Member of the Royal College of Surgeons and Licentiate of the Royal College of Physicians. Both Colleges have by-laws made by their respective Councils, and any Fellow, Member, or Licentiate found guilty of disgraceful conduct in any professional respect is liable to be disqualified and to have his name removed from the Register.

At the present time the Medical profession is under the control of the General Council of Medical Education and Registration of the United Kingdom, generally known as the "General Medical Council," which by the various Medical Acts had been given very wide powers. The Medical Acts do not prohibit the practice of medicine and surgery by unqualified persons; all that the Legislature has, by the Medical Acts, declared is, that it is expedient that persons requiring medical aid shall be enabled to distinguish qualified from unqualified practitioners.

Although registration is not compulsory, a qualified medical man cannot, unless he is registered, recover fees for advice or services, or charge for medicine prescribed or supplied; nor can he hold any public appointment, or give death or other

certificates required by Act of Parliament to be signed by a registered practitioner.

The General Medical Council have extensive powers over medical men, and can strike off the Register the name of any registered practitioner who has been convicted of felony or misdemeanour or adjudged by the Council to be "guilty of infamous conduct in a professional respect." The latter is a very wide phrase, and it is often a very open question as to what constitutes "infamous conduct." The Council are the sole judges of questions of fact in such cases, and there is no appeal from their decision.

Apothecaries, although not so numerous or well known as physicians and surgeons, constitute another class of medical men entitled to be registered. To practise as an apothecary a man (or woman) must be a Licentiate in Medicine and Surgery of the Society of Apothecaries. The Society were granted a charter of incorporation in the year 1618. An apothecary differs from a chemist in that he may apply and administer medicines, and determine what ought to be given, whereas a chemist may only prepare, dispense, and sell them.

The British Medical Association is a voluntary association, and is an example of a "trade union" within a general trades union, having for its objects the safeguarding of the rights of its members, and the maintenance of the honour, welfare, and dignity of the profession.

The advantage to its members of such a union was well illustrated in the prolonged negotiations with regard to medical service under the National Insurance Act, 1911, and without such a union it would have been impossible for the profession to obtain such terms of service as they did.

With regard to the Dental profession, statutory provision is made under the Dentists' Act, 1878, for the registration of dentists possessing certain specified qualifications.

For their better protection, dentists have organized the British Dental Association, the objects of which are similar to those of the British Medical Association, amongst them being "the promotion of Dental and the allied sciences and the maintenance of the honour and the interests of the Dental profession," and also "the maintenance of the spirit of the Dentists' Act by such lawful means as may be necessary."

The latter is a very necessary provision in view of the bad draftsmanship used in the Dentists' Act, 1878, and of the ease with which the Act can be evaded, the result being that anyone who does not actually use the word "dentist" may practise dentistry and even use the words "Dental Surgery," although he has no qualifications whatever.

This profession is an example of the danger of obtaining

statutory recognition unless the powers given are sufficiently stringent to safeguard fully the interests of its members.

Another profession having statutory recognition is that of a Solicitor, and, like the Medical profession, is of very ancient origin. Formerly, the word "Solicitor" applied only to persons who conducted suits in the Courts of Chancery, practitioners in the Courts of Common Law being known as Attorneys; but since the Judicature Act, 1873, all solicitors, attorneys, and proctors empowered to practise in any division of the High Court are called "Solicitors of the Supreme Court."

From 1739 to 1820 there existed an association of London attorneys and solicitors called "The Society of Gentlemen Practitioners in the Courts of Law and Equity." The Society established the right of London solicitors to do conveyancing work, which up till then had been claimed by the Scriveners' Company as their exclusive "mystery" or monopoly.

In 1825 a "Law Institution" was formed which subsequently became "The Incorporated Law Society." The Society introduced courses of lectures for students in 1833, and ten years later was constituted registrar of attorneys and solicitors. In 1877 the entire practical control of the examinations which a solicitor must pass was placed in the Society's hands.

In 1860 the Society obtained the power of suing unqualified solicitors, and in 1888 was given the custody of the roll of solicitors and also the power of investigating complaints as to the professional conduct of solicitors, as well as power to refuse to renew the annual certificate of a solicitor, subject, however, to the latter's right of appeal.

It is not necessary to be a member of the Incorporated Law Society in order to practise as a solicitor, but the majority of practising solicitors are members.

The training and education of a solicitor are carried out on strict lines. With certain exceptions he must be articled to a practising solicitor for a period varying from three to five years, during which time, as an "articled clerk," he must serve his master actually and continuously. He must also (unless exempted) pass the preliminary, and also the intermediate, and final examinations of the Law Society, and may then, if of age, apply to the Master of the Rolls to be admitted as a solicitor; and finally, on payment of fees amounting to £30, his name will be entered on the roll of solicitors. Even at this stage he is not entitled to practise until he has taken out an annual certificate expiring on the 15th of November in each year.

A solicitor may, on the application of some person aggrieved, be struck off the roll, or may be suspended, if found guilty of gross misconduct, whether professional or not, but the decision is subject to appeal, a procedure which has much to recom-

mend it when compared with that of the General Medical Council from whose decision no appeal is possible.

Together with other legal practitioners, a solicitor has practically a monopoly of legal business, and any person who wilfully and falsely pretends to be a solicitor, or takes any name, title, addition, or description implying that he is duly qualified to act as a solicitor, or that he is recognized by law as so qualified, is guilty of an offence and liable to a penalty of £10 for each offence, and is also liable for contempt of Court.

With regard to the remuneration of a solicitor, he is, like any other professional man, entitled to be paid for his services, but the law fixes the amount he may receive, and in the absence of agreement to the contrary he cannot claim more than the law allows.

An agreement by which the solicitor is to be paid only in the event of a successful action is void, as is also one under which the solicitor is to receive a proportion of the sum recovered.

The other branch of the legal profession—the Bar—is the most rigid example of a professional trade union, and has no statutory recognition.

To become a barrister, a man must be a member of one of the Inns of Court, of which there are four; all are of equal status, and are voluntary incorporated societies, independent of the State, and outside the jurisdiction of the Courts, but subject to the visitatorial jurisdiction of the Judges. In each inn there are three ranks, viz., Students, Barristers, and Benchers or Masters, the latter being the governing body. No one has any *right* either to be admitted as a student; to be called to the bar; or to be reinstated if expelled from the Society.

A barrister must not act in certain professions, including that of a solicitor; chartered, incorporated, or professional accountant; and while he is in practice as a barrister he must not engage in certain other occupations, including *inter alia* that of a land agent, surveyor, or consulting engineer.

If a barrister joins a circuit he may practise at the assizes and quarter sessions on that circuit, but not otherwise. He may attend any county court or police court, but a circuit is another example of a trade union within a general union, to which a member must first be elected before being entitled to accept a brief on that circuit, unless he is specially retained.

In the matter of fees, the rules of the bar prohibit any barrister from taking a fee of less than one guinea, and there is an additional fee of half-a-crown and upwards for his clerk, varying with the fee marked on the brief. The curious fact about these rules is that they are not codified nor have they statutory recognition, yet the custom is so firmly established that if a barrister

accepted a fee of less than a guinea he would probably find himself reported to the benchers of his inn. The payment of a barrister's clerk's fees are recognized and tabulated by the Rules of the Supreme Court, 1883.

The Bar Council is a voluntary body, consisting of barristers elected by the whole bar and supported by funds contributed by the four Inns of Court. It is the accredited "representative of the bar, and its duty is to deal with all matters affecting the profession, and to take such action thereon as may be deemed expedient." The Bar Council possesses no disciplinary powers, but in conjunction with the Attorney-General and Solicitor-General for the time being, and the benchers of the four Inns, it deals with matters concerning the professional etiquette of the bar, and brings to the notice of the benchers any gross violation of it.

A barrister cannot sue for his fees, even if the solicitor instructing him has received them, his remuneration being merely an honorarium, although he need not go into Court until his fee is paid. He is not liable for negligence, and is not obliged to return the fee even if he does not attend to a case.

Another profession recognised by Parliament is that of a Veterinary Surgeon. The Royal College of Veterinary Surgeons was founded in 1791, and received a charter of incorporation in 1845. Supplemental charters were granted in 1876 and 1879. The Veterinary Surgeons Act, 1881, was passed with a view to enabling the public to distinguish between qualified and unqualified practitioners. The diploma of the Royal College of Veterinary Surgeons is granted only to persons who have passed the examinations. A "Register of Veterinary Surgeons" is published annually, and anyone whose name is not on the register who uses any name, title, addition, or description stating that he is a practitioner of veterinary surgery is liable to a fine not exceeding £20, and cannot recover any fee for acting in any manner as a veterinary surgeon.

The Council of the Royal College of Veterinary Surgeons have power to remove from the register the name of any person who has been convicted of a misdemeanour or higher offence, or who has been guilty of any conduct disgraceful to him in a professional respect. The Council is elected by the profession; conducts all professional examinations, of which there are four; and grants the degrees of membership (M.R.C.V.S.) and of fellowship (F.R.C.V.S.). The course of study for the first degree is four years, the fellowship degree being obtainable, after having been in practice for five years, by passing a special examination.

The Pharmaceutical Society of Great Britain was founded in 1841, and obtained a Royal Charter in 1843. Its duties include the examination and registration of pharmaceutical

chemists and also of chemists' druggists, and the institution of proceedings against persons contravening the law.

Its object is the promotion of a uniform system of education for those who intend practising chemistry and pharmacy, and for the protection of those carrying on the business of a chemist and druggist. Anyone, however, may sell drugs (other than those containing poisons) provided he does not describe himself as a "chemist," "druggist," or "pharmacist," or other similar description.

In order to become entitled to be registered as a "chemist and druggist," a person must serve an apprenticeship of three years with a chemist and druggist, or a pharmaceutical chemist, during which period he receives a practical training. He must first pass an examination in general knowledge equivalent to the medical preliminary examination as required by the General Medical Council, and then the minor examination of the Parmaceutical Society.

A "pharmaceutical chemist" is a chemist and druggist who has passed the major examination of the Pharmaceutical Society, but any registered chemist and druggist may describe himself as a "pharmacist." This examination is in the nature of an "honours" examination. It is not necessary in order to be registered, but preference is often given to chemists who have passed it, in regard to public appointments.

Another association of professional men which the legislature has protected by registration is that of the Patent Agents. By the Patents, Designs, and Trade Marks Act, 1888, it is enacted that no person shall be entitled to describe himself as a patent agent (*i.e.*, one who acts in the obtaining of patents in the United Kingdom) whether by advertisement, by description on his place of business, by any document issued by him, or otherwise, unless he is registered as a patent agent under the Act.

The Board of Trade is empowered by the Act to make such rules as are necessary to give effect to this provision, and the Institute of Patent Agents is entrusted with the Register of Patent Agents and the duty of carrying out the necessary examinations for admittance to the profession of a patent agent. The Institute was incorporated by charter, and fellows of the Institute are entitled to call themselves chartered patent agents. Anyone falsely describing himself as a patent agent is liable, on conviction, to a penalty of £20.

With regard to Accountancy, accountants have made for themselves a strong position by means of professional societies of which there appear to be no fewer than ten in the United Kingdom; the earliest being the "Society of Accountants in Edinburgh," incorporated by Royal Charter in 1854.

To become a chartered accountant it is necessary to be

articled to a qualified accountant for five years, during which period the preliminary, intermediate, and final examinations are taken, and, if successfully passed, the society grants a certificate of professional qualification. As the law stands at present, however, there is nothing to prevent anyone calling himself (or herself) an accountant, and recovering payment for services rendered, although in practice it is most unusual to employ an auditor who is not a member of one of these societies. There is now before Parliament a bill "to provide for the Registration of Professional Accountants in Great Britain and Ireland."

The Stock Exchange is another example of a professional trade union, although, like others not possessing statutory recognition, it suffers considerably from outside competition. There is nothing to prevent anyone calling himself a stock and share broker, and all that he does is to bring together a willing purchaser and a willing seller, who otherwise would be unable to meet. That this can be done without the intervention of a broker has been demonstrated by the success achieved by a stock and share exchange organized by a daily newspaper.

The Stock Exchange is a company having a capital of 20,000 shares of £12 each with unlimited liability, and which yield a dividend of about £8 per share. Only members of the Stock Exchange can be shareholders, and the holding of any one member is limited to 200 shares. The shareholders elect a committee of "Managers," who are responsible for the up-keep and management of the building and correspond to directors in an ordinary company. There is another committee, elected annually by the members, which attends to the general working of the business.

In order to become a member of the Stock Exchange an applicant must be of age and must pay an entrance fee of 500 guineas. He must also acquire three shares in the Stock Exchange Company, and get three members to become sureties for him to the extent of £500 each for four years, in the event of his defaulting during that period. In addition to this, he must have perviously acquired, with the consent of the committee, a retiring or deceased member's "nomination" of membership, and also pay an annual subscription of 40 guineas.

All members of the Stock Exchange are subject to very stringent rules, one of which, prohibiting advertising, has the effect of putting members at a considerable disadvantage compared with the outside brokers, who can advertise to any extent and circularize the public in the same way as the unregistered dentist does.

Another professional union is that known as "Lloyd's." It is an association of marine underwriters, insurance brokers, merchants, bankers, shipowners, &c., of London, and its name originated from that of one Edward Lloyd, the proprietor of a

coffee-house in Tower Street, where, in the latter part of the 17th century, underwriters were accustomed to meet. In 1871 the society was incorporated by a special Act of Parliament.

" Lloyd's " forms the official centre for all shipping intelligence, having agents at all the principal ports throughout the world, and receiving daily reports of all sailings, arrivals, losses, casualties, and other information which may be of importance to shipping interests generally.

Another profession—that of the Architect—has proceeded as far as getting a Bill introduced into Parliament with a view to obtaining the registration of its members.*

That registration would, to a considerable extent, be an advantage to the architect is obvious, as it would close their profession. The question of remuneration would then probably arise, and no doubt Parliament would insist on a *maximum* charge, as is done by the Solicitors' Remuneration Act. From the architects' point of view it would be much more desirable to have a *minimum* rate fixed, as the present scale of fees fixed by the Institute is in many cases unremunerative in proportion to the amount of work and responsibility involved. Of course there is nothing to hinder an eminent architect from fixing his own percentage of remuneration, but competition is so keen that in most cases even an architect of high position and long standing finds himself compelled to accept the recognized five per cent. Possibly there would be less opposition to a minimum percentage now than there would have been formerly. If the working classes are to have a minimum wage, it seems unfair that the professional classes should be debarred from having one as well. Another advantage would be the ultimate elimination of the incompetent relation or friend of director or other person having the appointment of an architect, who is often " put in " for the job, and who would have to give place to a registered architect.

Apparently, Canada is the only Colony which requires the registration of architects. In Australia and other Colonies there appears to be no restriction on anyone who chooses to practise architecture, however, limited his knowledge and qualifications may be ; but in Natal an annual fee of £5 is charged for a license before a person can practise as an engineer and architect. There is also a Natal Institute of Architects which has for its object the promotion and advancement of architectural art and practice, and has power to make rules for the admission of members.

A good example of a professional union which has attained

* The steps taken by the Society of Architects to forward the principle of statutory registration for Architects, and the attitude of the Royal Institute of British Architects in regard to this question, have been fully reported and discussed recently in the technical press, and reference to them is therefore omitted from this abstract.

a prominent position largely due to the high standard if its examinations, is the Institution of Civil Engineers. This association was founded in 1818, and incorporated in 1825 by Royal Charter, for the general advancement of mechanical science and especially civil engineering. The Institution has no recognized scale of fees for the conduct of works, or designing, to correspond with that adopted by the Royal Institution of British Architects.

The Institute of Bankers, founded in London in 1879, is another professional union having a membership throughout the empire of over 5,600. The Institute holds annual examinations in subjects connected with banking, although no qualification is necessary for any individual or firm desirous of commencing business as a banker or so describing themselves, unless they are registered money-lenders.

The Auctioneers' Institute of the United Kingdom (Incorporated) is a union of Auctioneers, Estate Agents, and Valuers, for the purpose of elevating the status and procuring the advancement of the interests of the profession, and to provide for its protection by holding examinations and issuing certificates to successful candidates. The Institute has prepared a scale of professional charges for sales by auction, valuations, &c., but there is nothing in the Articles of Association to prevent a member making what terms he likes with his client.

Certain allowances to Auctioneers and Surveyors have been specified in an order made under the Bankruptcy Acts, 1883 and 1890, for the preparation of inventories, and for sales by auction, dilapidation surveys, &c., but the charges are subject to reduction by agreement with the Official Receiver or the Trustee, or to increase with the sanction of the Committee of Inspection and the Receiver.

At present any person of either sex is entitled to act as an auctioneer provided they obtain an auctioneer's licence, for which a duty of £10 is charged, and which is valid only for a year or part of a year expiring on the 5th of July. No licence is, however, required to sell by auction under an Order of the Court, or under a distress for rent for any amount less than £20.

Dealing now with Surveyors, we find that the Surveyors' Institution was established in 1868, and incorporated by Royal Charter in 1881. The question of registration is not one which comes within the objects of the Institution.

There is no legal definition of, or restriction on, the use of the word "surveyor," although in several Acts of Parliament mention is made of questions which are to be dealt with by surveyors, *e.g.*, under the Lands Clauses Act, 1845, where compensation is to be determined by an "able and practical surveyor"; under the London Building Act, 1894, where

"District Surveyors" must have passed the examination held by the Royal Institute of British Architects for that purpose, but in party wall disputes no qualification is necessary in order to act as surveyor. Nor is any qualification necessary for the position of surveyor under the Ecclesiastical Dilapidations Act 1871, except that he shall be a "fit person."

It is not until we come to the Finance (1909-10) Act, 1910, that we find the Surveyors' Institution recognized in an Act of Parliament. Under this Act, in the case of an appeal, the President of the Institution is to be one of the Reference Committee, and referees are to be appointed to hear appeals, who shall be Fellows of the Surveyors' Institution, or other persons having experience in the valuation of land. This is valuable testimony to the excellent work which has been done by the Surveyors' Institution, as a professional "union," in getting its diploma recognized as the highest standard of professional ability.

The power given to Fellows of the Surveyors' Institution to adopt the title "Chartered Surveyor," does not at present appear to be of any particular value to its members, since I doubt if the expression conveys any particular idea to the general public. "Chartered Accountant" is a well-known term which is readily understood; but as the members of the Surveyors' Institution are really divided into three branches, viz., land agency, valuation and estate agency, and building and quantity surveying, the fact that a member calls himself a chartered surveyor is no indication as to which branch of the profession he belongs. No one man can be expected to be an expert in all three branches.

The Quantity Surveyors' Association has among its objects to provide a distinctive and central organization for Quantity Surveyors, and to do what may be necessary to elevate the status and procure the advancement of the profession by a system of examinations and otherwise.

The only effective way to achieve these results is by Registration on similar lines to those in the Bill dealing with Registered Accountants, to which I have already referred. The position of a Quantity Surveyor is in some respects similar to that of an accountant, but in addition to a knowledge of figures a large amount of purely technical knowledge is indispensable.

In the Colonies the registration of surveyors is, of course, a comparatively easy matter to organize, especially in the newer states, where the population is small and the government is unhampered with existing customs and prejudices.

In Canada, a land surveyor cannot practise until he has passed the examination of the Board of Examiners.

The different provinces of Canada have different regulations. In each case an examination has to be passed, and articles have

to be served during a period of three or four years, such term being reduced to one year if the candidate has taken some recognized university or college course in addition. A year or more of work in the field is also necessary. In Australia, Tasmania and New Zealand we find similar regulations.

In Cape Colony the surveyor must qualify in Cape Colony, no foreign diploma or certificate being recognised. The "Institute of Government Land Surveyors of the Cape of Good Hope" is the controlling authority.

In Natal there is the "Institute of Land Surveyors of Natal." In the Transvaal, Orange River Colony, and Rhodesia similar regulations prevail.

This, I think, concludes the list of professional "Unions." There may be others, less known, but those I have mentioned sufficiently indicate the tendency of modern times for each profession to specialize and to form societies for their advancement and protection.

With the exception of the Medical and Legal professions, it is noticeable that all these unions are of comparatively recent origin. Another remarkable circumstance is that in each case where statutory recognition has been obtained, it has been achieved by the efforts of the members of the particular profession, and is not due in the first instance to Parliament.

That registration is the outcome of modern requirements is abundantly shown by the action of the Colonies in requiring the registration of professions which in the Old Country can be carried on by anyone, although in all probability before many years have elapsed this wise rule will be general here as well.

The demand for registration is no doubt occasioned in some degree by increased competition among professional men and the higher standard of efficiency required in those unions which hold examinations prior to the admission of members. It is to be observed that, where registration is compulsory, the serving of proper articles of apprenticeship is obligatory, and has much to recommend it.

To summarise; the advantages of registration appear to be these:—

- The standardisation of the qualification of members, at all events as regards a *minimum* qualification.
- Powers of discipline over the members in regard to their professional conduct; powers which are especially effective where such conduct is not within the purview of the law.
- Regulation of fees paid to members of the profession.
- A closer union in the profession by reason of these three principal advantages.
- A general uplifting of the tone and character of the profession by reason of its recognised disciplinary organization.

NOTES ON THE WATER SUPPLY OF GREATER NEW YORK.

REPLY TO THE DISCUSSION.

BY

WILLIAM T. TAYLOR, M.I.E.E., M.Inst.Mun.E., M.Am.Soc.M.E.

Mr. Taylor's paper was read at a Joint Meeting with the Institution of Municipal Engineers, held on May 11*th*, 1914, *and is printed on page* 167 *of the Transactions. Owing to Mr. Taylor's absence in Bolivia it was impossible for him to reply to the discussion at the time, but he has now sent the following remarks for publication.*

When one responds from the other end of the earth, both distance and time are very noticeable. Since the reading of this paper and its discussion, the author's business has taken him to far off Bolivia (South America) in connection with a £2,000,000 hydraulic engineering undertaking. A considerable amount of time must, therefore, pass before a reply to the discussion can come before the members of the Society.

Not unlike several of the speakers and perhaps many members present, I have been, for several years past, particularly interested in, though not directly connected with, the New York Water Supply scheme. In a stupendous work of this kind it seemed to me that the proper way to treat the subject and to make it of sufficient interest was to summarize the most valuable and interesting features of the work, and leave all the minor details for future notice when work of a similar nature is to be accomplished. It is, of course, quite reasonable to expect divided opinions from British and American water engineers, but there is much in this Catskill scheme that is of interest to water engineers in England, and, as stated by Dr. Herbert Lapworth, there is quite a deal to learn from it.

The discussion is of especial interest to me, and what seems unique is the distinct effect on the part of two representative English engineering societies, entirely different in character and constitution, co-operating in a friendly manner for the discussion of this subject. May this be the forerunner of other joint meetings when papers of interest to two or more societies are to be read.

There are so many thousands of details to be considered when one enters into the scheme thoroughly that to begin and complete the subject matter, as it was my object to do

in one paper, would require at least several " fat " books. The scheme is so large that, if details are dealt with, sections of the work must be treated in separate papers. I therefore did not propose to go quantitatively into the scheme as President Shenton would have desired, in fact one paper could not possibly have covered the " many points of detail in the scheme."

Concrete-lined tunnels and the lining of steel mains with cement were finally decided upon after several years of experience in various parts of America. My personal observations on the spot and experience of work of a similar character, and the workmanship of the American mason, leave no doubt in my mind that this type of tunnel is quite watertight. An interesting feature of the cement-steel water mains was the electric welding of the steel tubes.

The concrete core dam construction is an old American fashion, and the puddle core dam construction is an old British fashion. Both types of construction are based on experience and many very large dams of both types exist to-day in various parts of the world, and are quite satisfactory. It is reasonable to suppose that a settlement of the earth will bend the core to one side if the embankment is not properly proportioned and if a reinforced core is not provided. I have seen several concrete core dams of large dimensions built and used in a very satisfactory manner, quite as satisfactory as any dam of puddle construction. It appears to me that the difference more worthy of mention is their relative cost. Personally if I had a plentiful supply of puddle near by I would seriously consider its use as against the cost and disadvantages of a concrete core dam construction. Mr. Sandeman is, I can see, entirely in favour of a puddle construction at all times, even when puddle is brought from a distance, and, I do not hestitate to say that I believe Mr. Sandeman can base his own experience of many years on the reliability of this kind of construction. It would be of special value and interest to the Society if Mr. Sandeman had presented quantitive costs per cubic yard of puddle in place, including cartage, etc., to the site, so as to compare with Table I. (pp. 244-5), which shows the quantities of materials required for one cubic yard of rammed concrete. I have purposely omitted costs of cement per barrel, and sand and stone per cubic yard for the different mixtures, for the reason that they are ever variable, whereas the relative quantities shown here are constant and can be relied upon at all times and in any place.

As regards water supply in all its phases, I am quite in agreement with Dr. Lapworth that we have much to learn from this branch of American engineering practice. At the present time the Americans have, as a whole, the largest developments in the world of water supply and water power, and yearly we see

larger and larger undertakings projected, such as we have not yet thought out in England. When one considers the engineering features of certain navigation schemes, as the 300 mile Barge Canal, costing £22,000,000, and some of the irrigation schemes of the West and Middle Western States, as also numerous huge water-power developments—as for instance that on the Mississippi River, which will, when completed, have a power station a quarter of a mile long and an effective capacity of 300,000 h.p.—it is impossible to avoid being very greatly impressed with the significance of their ventures.

The total cost of a given work is the factor which vitally interests the engineer in his capacity of manager for a party contracting for a given work; the total cost being, of course, the contract price plus the costs of surveys and designs, plus the costs of inspection, superintendence and interest on the moneys invested by partial payments or otherwise, the greater part of the latter varying almost directly with the time taken to do the work. The interest, and inspection costs, etc., will be less with a decrease in contract time, but cost of equipment, etc., necessary to complete the given work in less time will be greater, such as, for example, the cost of plant employed on the New York Water Supply works and mentioned by Mr. Sandeman. There is evidently a time which will give the minimum total costs for a given work.

In the past, and even at the present time very little uniformity in figuring contract-time has been and is being generally used. Several methods of local types have been tried but a very broad method is badly needed which will combine the confidence of the Contractors in general and the absolute fairness and broad experience of the Engineer-Manager. Practically 90 per cent. of such work in the past has been purely guess-work based on local experience or taken from certain contracts executed in different localities under different local conditions, etc., all of which are more or less misleading. Where work, particularly of such magnitude, is let out by contract, a system must be adopted whereby the best all-round results are known in advance; the least total cost, the contractor's economical time, the contractor's costs, interest, inspection, and other time charges, and the contract time in working hours or days, as well as the starting time of certain contracts and the point where certain contract work will cross. The basis for such reasoning is shown in Figure I., where the Contractor's cost curve shows the variation in cost with the Contract Time in working days, it being marked Curve (A.). The variation of this and Curve (B.), with the Curve (C.) of Total Costs should, for the most economical condition, follow the relations shown here; of course, none of these curves are treated quantitively, that is to say, they do not show

TABLE I.

QUANTITIES OF MATERIAL IN CEMENT REQUIRED FOR A CUBIC YARD OF RAMMED CONCRETE.

Mixture.			Stone 1 in. and under, dust screened out.			Stone 2·5 in. and under, dust screened out.			Stone 2·5 in. with most small stone screened out.			Gravel 0·75 in. and under.		
Cement	Sand.	Stone.	Bbls. of Cement.	Sand. Cu. Yds.	Stone. Cu. Yds.	Bbls. of C ment	Sand. Cu. Yds.	Stone. Cu. Yds.	Bbls. of Cement.	Sand. Cu. Yds.	Stone. Cu. Yds.	Bbls. of Cement.	Sand. Cu. Yds.	Stone. Cu. Yds.
1·0	1·0	2·0	2·57	0·39	0·78	2·63	0·40	0·80	2·72	0·41	0·83	2·30	0·35	0·74
1·0	1·0	2·5	2·20	0·35	0·70	2·34	0·36	0·89	2·41	0·37	0·92	2·10	0·32	0·80
1·0	1·0	3·0	2·06	0·31	0·94	2·10	0·32	0·96	2·16	0·33	0·98	1·89	0·29	0·86
1·[illegible]	1·0	3·5	1·84	0·28	0·98	1·88	0·29	1·00	1·88	0·29	1·05	1·71	0·26	0·91
1·0	1·5	2·5	2·05	0·47	0·78	2·09	0·48	0·80	2·16	0·49	0·82	1·83	0·42	0·73
1·0	1·5	3·0	1·85	0·42	0·84	1·90	0·43	0·87	1·96	0·45	0·89	1·71	0·39	0·78
1·0	1·5	3·5	1·7[illegible]	0·39	0·91	1·74	0·40	0·9	1·79	0·41	0·[illegible]6	1·57	0·36	0·83
1·0	1·5	4·0	1·57	0·36	0·96	1·61	0·37	0·98	1·64	0·38	1·00	1·46	0·33	0·88
1·0	1·5	4·5	1·43	0·33	0·98	1·46	0·33	1·00	1·51	0·35	1·06	1·34	0·31	0·91
1·0	2·0	3·0	1·70	0·52	0·77	1·73	0·53	0·79	1·78	0·54	0·81	1·54	0·47	0·73
1·0	2·0	3·5	1·75	0·48	0·83	1·61	0·49	0·85	1·66	0·50	0·88	1·44	0·44	0·77
1·0	2·0	4·0	1·46	0·44	0·89	1·48	0·45	0·90	1·53	0·47	0·93	1·34	0·41	0·81
1·0	2·0	4·5	1·36	0·42	0·93	1·38	0·42	0·91	1·43	0·43	0·98	1·26	0·38	0·86
1·0	2·0	5·0	1·27	0·39	0·97	1·29	0·39	0·98	1·33	0·39	1·03	1·17	0·36	0·89
1·0	2·5	3·5	1·45	0·55	0·77	1·48	0·56	0·79	1·51	0·58	0·81	1·32	0·50	0·70
1·0	2·5	4·0	1·35	0·52	0·82	1·38	0·53	0·84	1·42	0·54	0·87	1·24	0·47	0·75
1·0	2·5	4·5	1·27	0·48	0·87	1·29	0·49	0·88	1·33	0·51	0·91	1·16	0·44	0·80
1·0	2·5	5·0	1·19	0·46	0·91	1·21	0·46	0·92	1·26	0·48	0·96	1·10	0·42	0·83
1·0	2·5	5·5	1·13	0·43	0·94	1·15	0·44	0·96	1·16	0·44	0·99	1·03	0·39	0·86
1·0	2·5	6·0	1·07	0·41	0·97	1·07	0·41	0·98	1·10	0·41	1·13	0·98	0·37	0·89

1·0	3·0	4·0	1·26	0·58	0·77	1·28	0·58	0·78	1·32	0·60	0·80	1·15	0·52	0·72
1·0	3·0	4·5	1·18	0·54	0·81	1·20	0·55	0·82	1·24	0·57	0·85	1·09	0·50	0·75
1·0	3·0	5·0	1·11	0·51	0·85	1·14	0·52	0·87	1·17	0·54	0·89	1·03	0·47	0·78
1·0	3·0	5·5	1·06	0·48	0·89	1·07	0·49	0·90	1·11	0·51	0·93	0·97	0·44	0·81
1·0	3·0	6·0	1·01	0·46	0·92	1·02	0·47	0·93	1·06	0·48	0·97	0·92	0·42	0·84
1·0	3·0	6·5	0·96	0·44	0·95	0·98	0·44	0·96	1·00	0·45	1·01	0·88	0·40	0·87
1·0	3·0	7·0	0·91	0·42	0·97	0·92	0·42	0·98	0·94	0·42	1·05	0·84	0·38	0·89
1·0	3·5	5·0	1·05	0·56	0·80	1·07	0·57	0·82	1·11	0·59	0·85	0·96	0·50	0·76
1·0	3·5	5·5	1·00	0·53	0·84	1·02	0·54	0·85	1·06	0·56	0·89	0·92	0·48	0·78
1·0	3·5	6·0	0·95	0·50	0·87	0·97	0·51	0·89	1·00	0·53	0·92	0·88	0·46	0·80
1·0	3·5	6·5	0·92	0·49	0·91	0·93	0·49	0·92	0·96	0·51	0·95	0·83	0·44	0·82
1·0	3·5	7·0	0·87	0·47	0·93	0·89	0·47	0·95	0·91	0·49	0·98	0·80	0·43	0·85
1·0	3·5	7·5	0·84	0·45	0·96	0·86	0·45	0·98	0·86	0·47	1·01	0·76	0·41	0·87
1·0	3·5	8·0	0·80	0·42	0·97	0·82	0·43	1·01	0·83	0·45	1·04	0·73	0·39	0·89
1·0	3·5	5·0	1·05	0·56	0·80	1·07	0·57	0·82	1·11	0·59	0·85	0·96	0·50	0·76
1·0	3·5	5·5	1·00	0·53	0·84	1·02	0·54	0·85	1·06	0·56	0·89	0·92	0·48	0·78
1·0	3·5	6·0	0·95	0·50	0·87	0·97	0·51	0·89	1·00	0·53	0·92	0·88	0·46	0·80
1·0	3·5	6·5	0·92	0·49	0·91	0·93	0·49	0·92	0·96	0·51	0·95	0·83	0·44	0·82
1·0	3·5	7·0	0·87	0·47	0·93	0·89	0·47	0·95	0·91	0·49	0·98	0·80	0·43	0·85
1·0	3·5	7·5	0·84	0·45	0·96	0·86	0·45	0·98	0·86	0·47	1·01	0·76	0·41	0·87
1·0	3·5	8·0	0·80	0·42	0·97	0·82	0·43	1·01	0·83	0·45	1·04	0·73	0·39	0·89
1·0	4·0	6·0	0·90	0·55	0·82	0·92	0·56	0·84	0·95	0·58	0·87	0·83	0·51	0·77
1·0	4·0	6·5	0·87	0·53	0·85	0·88	0·53	0·87	0·91	0·55	0·90	0·80	0·49	0·79
1·0	4·0	7·0	0·83	0·51	0·89	0·84	0·51	0·90	0·87	0·53	0·93	0·77	0·47	0·81
1·0	4·0	7·5	0·80	0·49	0·91	0·81	0·50	0·93	0·84	0·51	0·96	0·73	0·44	0·83
1·0	4·0	8·0	0·77	0·47	0·93	0·78	0·48	0·95	0·81	0·49	0·98	0·71	0·43	0·86
1·0	4·0	8·5	0·74	0·45	0·95	0·76	0·46	0·98	0·78	0·47	1·01	0·68	0·42	0·88
1·0	4·0	9·0	0·71	0·43	0·97	0·73	0·44	1·01	0·75	0·45	1·04	0·65	0·40	0·89
1·0	5·0	9·0	0·66	0·50	0·90	0·67	0·52	0·93	0·70	0·53	0·96	0·61	0·46	0·83
1·0	5·0	10·0	0·62	0·47	0·95	0·63	0·48	0·96	0·65	0·50	1·00	0·57	0·43	0·87

NOTE.—A barrel of Portland cement contains about 4 c.ft., weighing about 380 lb.

Where
(A) is the curve of Total Costs.
(B) is the curve of Contractor's Costs.
(C) is the curve of Interest and total Charges.

And
(a) Least Total Cost.
(b) Proper Contract Time.
(b′) Contractor's Economical Time.
(b″) Contractor's Least Cost.

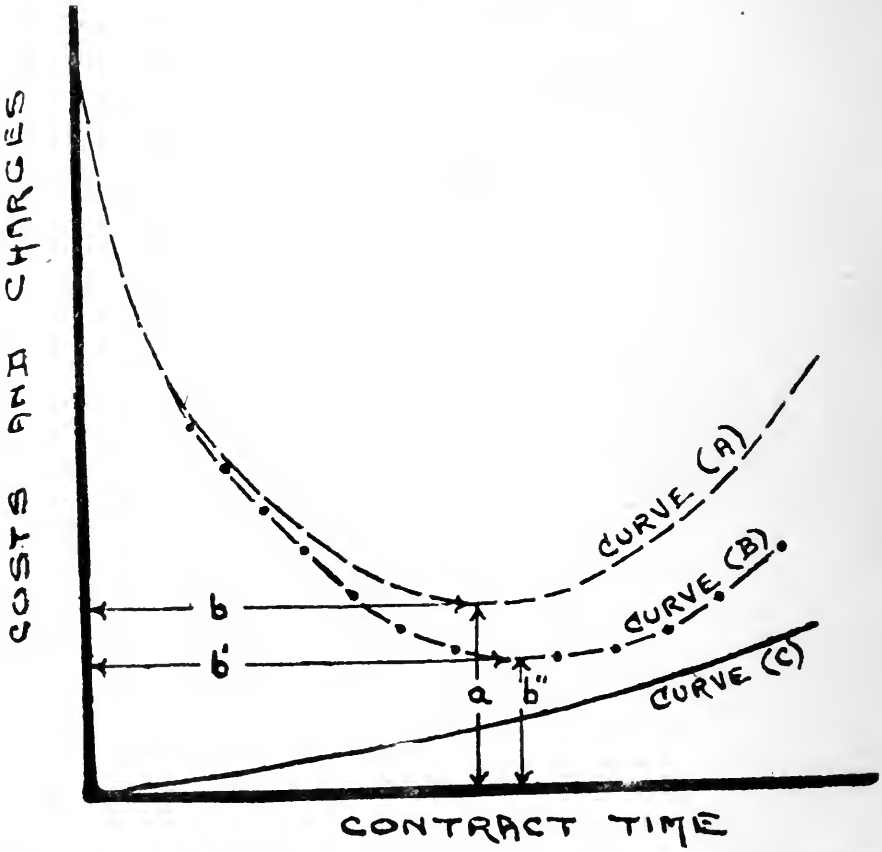


FIG. 1.—BASIC METHOD FOR THE DETERMINATION OF THE TIME WHICH SHALL BE ALLOWED FOR THE COMPLETION OF A GIVEN CONTRACT.

variations with regard to quantity or other conditions governing any sort of work, but it is a very simple matter to plot one such set of curves for a given work which will determine the proper contract time for each total quantity of each kind of work, and the proper contract time against the total quantities.

For example, engineers—municipal engineers in particular—very often want to determine quickly and accurately such problems as :—

(*a*) What number of days shall be written into a Contract for the completion of a given work ?

(*b*) Where one Contract covers different sorts of work, requiring partly or wholly different equipments for each sort, what number of working days shall be allowed for the completion of the Contract ?

(*c*) Should or should not urgent or emergency work—in proportion to their needs—sacrifice economy for time ?

(*d*) Should work of a maintenance nature look only to economy of total cost and disregard contract time ?

There is a considerable difference in judgement as to the most economical plant for any given contract time and total quantity of work to be done, and also a great difference in judgement as to the delays and other items summed up in the Contractor's costs. By the equalization of such items as superintendence, inspection, interest and similar time charges with the increased cost of obtaining and operating equipments of more capacity than are required to complete a given Contract in the "Contractor's economical time," using that point with reference to time which gives the least total cost, the *correct time* to allow for the Contract is obtained. Also, by plotting the times allowed on previously completed contracts composed mainly of one kind of work and which had been prosecuted vigorously and with adequate equipment, the engineer can draw a series of curves in terms of *quantity* and *time* for each kind of work, each curve recognising in its equation some particular controlling factor of variation. Equipped with such curves and knowing the total quantity of work to be done, the engineer can ascertain the proper contract time, and the results may be combined to give him the time for a contract including different sorts of work. So we see that although £500,000 was invested in plant alone for the completion of the two great dams, we must know the conditions governing the case before criticising.

I think Mr. Horace Boot (President of the Institution of Municipal Engineers), when discussing the paper, unconsciously answered the question brought up by Dr. Eric Rideal, Mr. J. D. Haworth, Mr. Henry C. Adams and others relative to water consumption per head per day ; in his remarks : "If they traced the history of the water supply of our great towns they found that the town councillors generally could not bring themselves to realize that their cities must grow and the requirements increase." Also the point " . . . in the future when they came to design a water scheme they would be encouraged to put forward a sufficiently large one." The per capita basis of 100 gallons is an excellent basis upon which to design any scheme for domestic consumption of water. In the largest towns of the United States of America this basis is scarcely sufficient, but in general it is a good mean, and is used by all water

engineers. The water engineers of the New York Water Supply scheme showed great foresight and estimated in the right direction when they applied this basis to the estimated population of Greater New York up to the year 1940. To issue less than the available quantity of water is a simple matter and one which can be regulated at all times and at any place, but to meet an average demand for several weeks in the year for 20 to 50 per cent. more water than the average, and to forget that the population must grow, etc., is an entirely different matter and one not usually looked at so broadly as by the engineers of New York. They very wisely paid no attention to the most economic domestic water consumption. What was uppermost in their minds was the maxiumm demand for which they had to design and build, not for the present population nor the present day, but for a population of approximately 9,000,000 and for 25 years to come at the least.

The proper relationship between the dimensions of a water supply scheme and the total population to be supplied will always evoke diverse opinions. The proper ratio will reduce itself to the quantity of water required per head per day. To build for to-day and on the basis of economical water consumption or in other words to design a water supply scheme on the basis of expenditure necessary to reduce consumption against the expenditure necessary to increase the supply for to-day is poor policy; but in designing a water supply scheme for a fast growing city of the size of New York, the factor of economical water consumption becomes of secondary consequence because a maximum demand capacity must be provided for, and although unnecessary consumption is checked and the water saved and stored, the most economical design must work out on some basis of time and increase of population against the fixed factor of consumption per head of time. This fixed factor of maximum consumption will include the regular population plus "commuters" and other "transients" which are variable from time to time. Thus, the fundamental factors for any design are: maximum consumption, increase of population and time in years. If a saving of water consumption is afterwards accomplished it can be added to time and increase of population. It is, of course, generally speaking cheaper to reduce consumption than build for greater supply.

It is quite true as Mr. Boot says that " . . . one was struck by the small, inadequate water schemes which were so often carried out by our (English) municipalities." They should, as he says, not be afraid of dealing with a water supply on a large scale, but should use reason. As an example of municipal engineering on a large scale, built entirely by the City's engineering department and forces, take the City of Los Angeles aqueduct,

233 miles long and bringing an abundant water supply to the City and affording opportunity for installing hydro-electric plant of 120,000 h.p. The cost of this work was nearly £5,000,000. The length of the aqueduct is constituted of : 61 miles of canal ; 98 miles of covered conduit ; 43 miles of tunnels ; 12 miles of syphons ; 8 miles of water storage in reservoirs ; 10 miles of water-power tunnels and waterway, and a quarter of a mile of flume. We see here a combined water supply and water-power undertaking, engineered and carried out entirely by its own engineering force—surely this should be a good example to place before some town councillors.

The figures for domestic and industrial water consumption in Manchester as given by Mr. J. D. Haworth are of interest, but nevertheless it would be very misleading to compare Manchester or any of its surroundings with towns in the United States of America, in fact I think I am safe in saying that even from the point of view of the relative number of baths installed and in use in dwellings, they are fifty to one in favour of New York City to Manchester. In considering the relative water consumption as a whole it is very much like comparing many parts of South America or even Mexico with England—there is no comparison—owing largely to the habits of living, etc.

Dr. S. Rideal remarked about the purification of the water supplied to the city from these large reservoirs. On this question I am not posted with the latest developments, but I do know that the board of engineers repeatedly recommended to the city authorities certain purification plant, their recommendations being rejected time and time again for some reason or other. Several methods of purification have been put forward and one such finally accepted ; the evil-smelling "spongilla," etc., and the organic growths will fairly well be avoided on account of the concrete lining of tunnels.

Before recommending members to take up the book recently published by Lazarus White, which gives an account of the construction, etc., of the Catskill Water Supply, I would ask them first to consult the New York reviews on that book from engineers closely associated with the undertaking. All those members desiring an accurate account of the entire scheme cannot do better than consult the library of the Institution of Municipal Engineers, which contains the annual reports of the board of water supply of New York for the years 1905-1912. These seven handsome and splendidly illustrated volumes give the whole history of the New York water supply from the very beginning. Also, should members desire a copy of any of the Contracts, with a complete set of drawings with each Contract, he can, I think, purchase one or more Contract sets from the

Departmental Engineer. In this, I am only speaking from my own experience but fully believe that members going through the right channel will find no difficulty in securing valuable contract specifications, drawings, photographs, etc., covering special sections of the work of which they are particularly interested. In fact, I recommend that the Society of Engineers or the Institution of Municipal Engineers obtain for theirs libraries a complete set of these specifications and drawings for the benefit of the members.

5th October, 1914.

H. C. H. SHENTON, President,

in the Chair.

CYLINDER BRIDGE FOUNDATIONS IN THE EAST AND THE CONSTRUCTION OF THE SITTANG RIVER BRIDGE, BURMA RAILWAYS.

By A. Stewart Buckle, M.C.I.

[Member.]

This paper deals with the construction of the Sittang River Bridge in Lower Burma (the longest bridge over any river in Burma), on which work, with 52 miles of the Pegu-Moulmein Railway, the author was engaged as Executive Engineer. An account is also given of the author's experience in cast iron cylinder sinking during the construction of a series of bridges connecting Mannar Island with Ceylon on the recently completed Indo-Ceylon connection railway.

The Sittang Bridge forms one of the links in the Pegu-Moulmein Railway, 121½ miles in length, a railway that virtually connects Rangoon and Moulmein, two of the most important ports of Burma. The railway was opened for passenger traffic in September, 1907.

The map (p. 252) clearly shows the position of these two ports with the estuary of the Sittang River, and the general alignment of the Pegu-Moulmein Railway. Incidentally this map also shows the remarkable changes in the coast line which have occurred during a period of less than twenty years, partly due, no doubt, to the action of a tidal bore which runs up this estuary at every full and new moon for about four days at a time.

The existence of this bore is clearly due to the meeting of the two flood tides in the estuary of the Sittang, the one flowing up the Rangoon shore of the Gulf of Martaban, and the other up the Moulmein shore.

It was fortunate that the bore did not reach the site of the bridge during the time that it was under construction, since there is evidence that at one time the bore did extend so far, and it was easy to foresee, from conditions that will be explained later, that it was practically certain to do so again. It did, however, run up one of the tributary rivers of the Sittang in a wave about 6ft. high, travelling at eleven miles an hour, and added considerably to the difficulties of bridging that river.

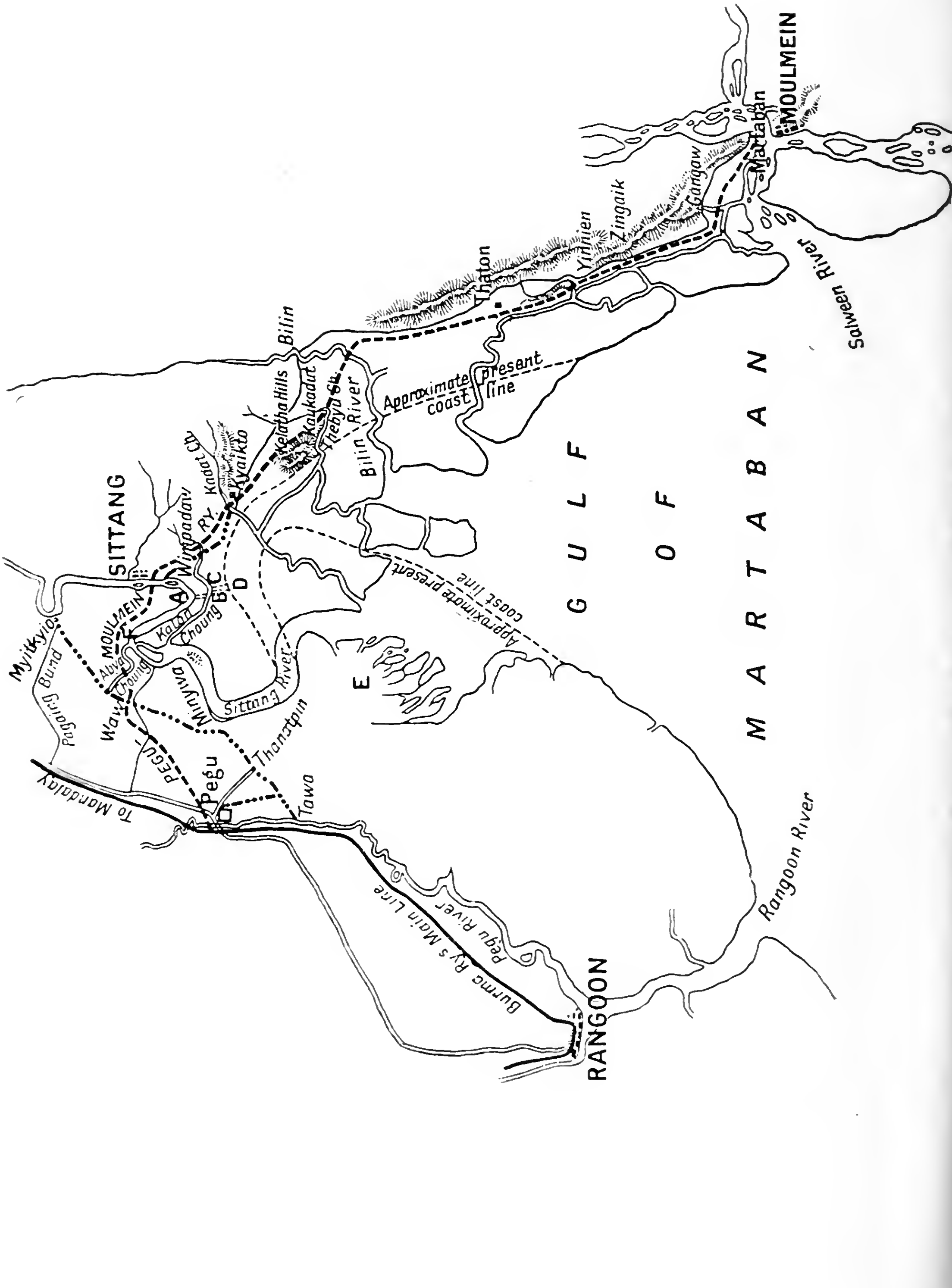


FIG. 1.—PLAN SHOWING MOUTH OF SITTANG RIVER

JOURNAL OF THE SOCIETY OF ENGINEERS (INCORPORATED),
October, 1914.

Fig 2

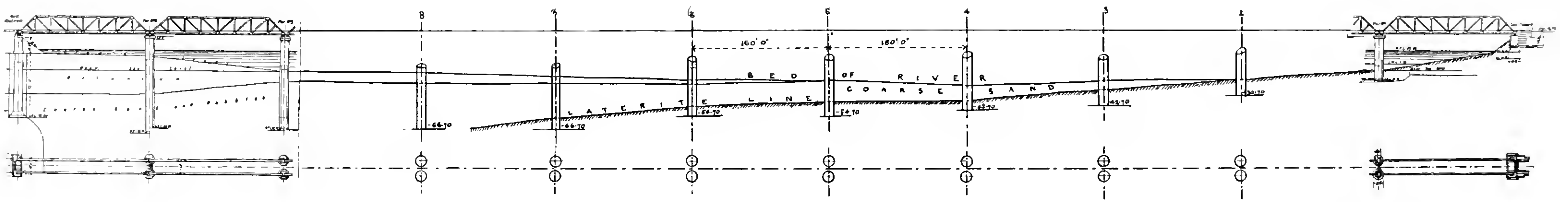


Fig 3

FIGS. 2 AND 3.—SECTION AND PLAN OF SITTANG RIVER BRIDGE.

The Sittang River at the place selected for the bridge is about 1,600ft. across (Figs. 2 and 3). The maximum depth at low water was about 24ft., but this was increased by scour after the first season's work to 27ft. Owing to the unusual depth of water it was decided to use double cast iron cylinders of 10ft. diameter each for piers, in preference to the brick or masonry wells usually adopted in India. Eleven spans of 150ft. each, or 160ft. centre to centre of the piers, were decided upon, making the bridge 1,760ft. in length and providing one land span.

Caissons sunk by the pneumatic sinking process would probably have been adopted in this country, but in the East, from motives of economy, pneumatic sinking is only resorted to when there is a hard rock foundation. The Indian system of well sinking by open dredging for bridge foundations has developed along lines of its own, and the author does not know why it is so seldom, if ever, used in this country for bridge foundations.

Although this system is well known to those who have worked in India, the author believes there are many engineers to whom it is not so familiar.

Well System of Bridge Foundations.—Circular wells from about 16ft. outer diameter upwards were at first, and are still, used for smaller bridges. The pier in this case is built on a single well, corbelling out of the top of the well being resorted to if necessary to obtain sufficient bearing for the pier. When very long piers became necessary in large span bridges the circular form of well developed into an oval form with two dredging holes. In this form, however, it was found that there was much masonry area under which the dredger could not operate. Sir Francis Spring, K.C.I.E., therefore brought out the double octagonal form of well, the two octagons being connected by a common side, and this is the form now generally adopted. The well or pair of wells is built on a steel well curb, and islands are first made in the river on which the well curb is placed. In most of the large rivers of India the river is so much reduced in the dry season that it is a comparatively easy matter to form islands, and the water may often be confined to half the width of the river during one season, and then diverted to the other half in the following season.

Under these conditions the well system with open dredging generally proves very satisfactory, provided the bed is not hard rock. It is necessary, however, to provide a large supply of bricks or stone before operations of any magnitude can be begun. Wells are, of course, also adapted for deep water foundations by lengthening the well curb and so forming caissons. They have the great advantage over cylinders of allowing more play in every way; for any small errors from the vertical or of position that may be found after sinking is completed can easily be adjusted when the base of the pier is set out on top of the wells.

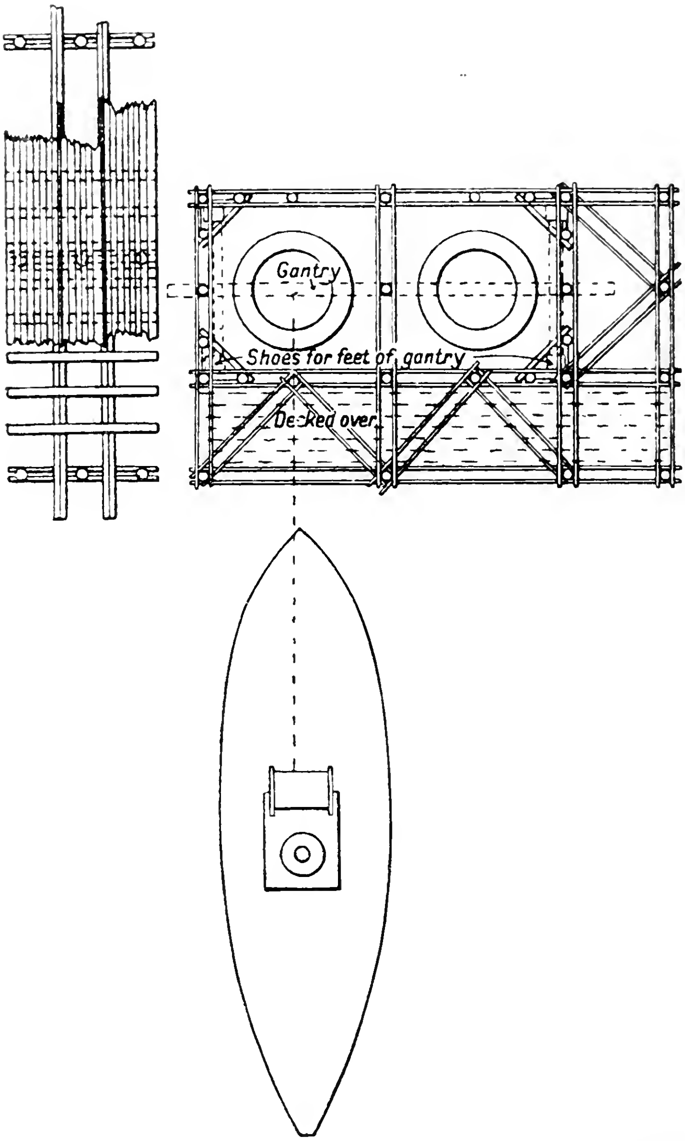


Fig. 4.—Plan of Staging used when Sinking Cylinders. Sittang River Bridge.

Cylinders and depth of water in Sittang River.—The Sittang River at the bridge site was so near its mouth that, being affected by the tide, its volume of water was not much reduced in the dry season.

For deep water foundations such as this there is much to be said in favour of cast iron cylinders, though probably concrete cylinders would have served the purpose equally well and saved the cost of manufacture and transport of the cast iron. They are comparatively easily placed in position without the necessity of making islands, and the provision of a large supply of brick

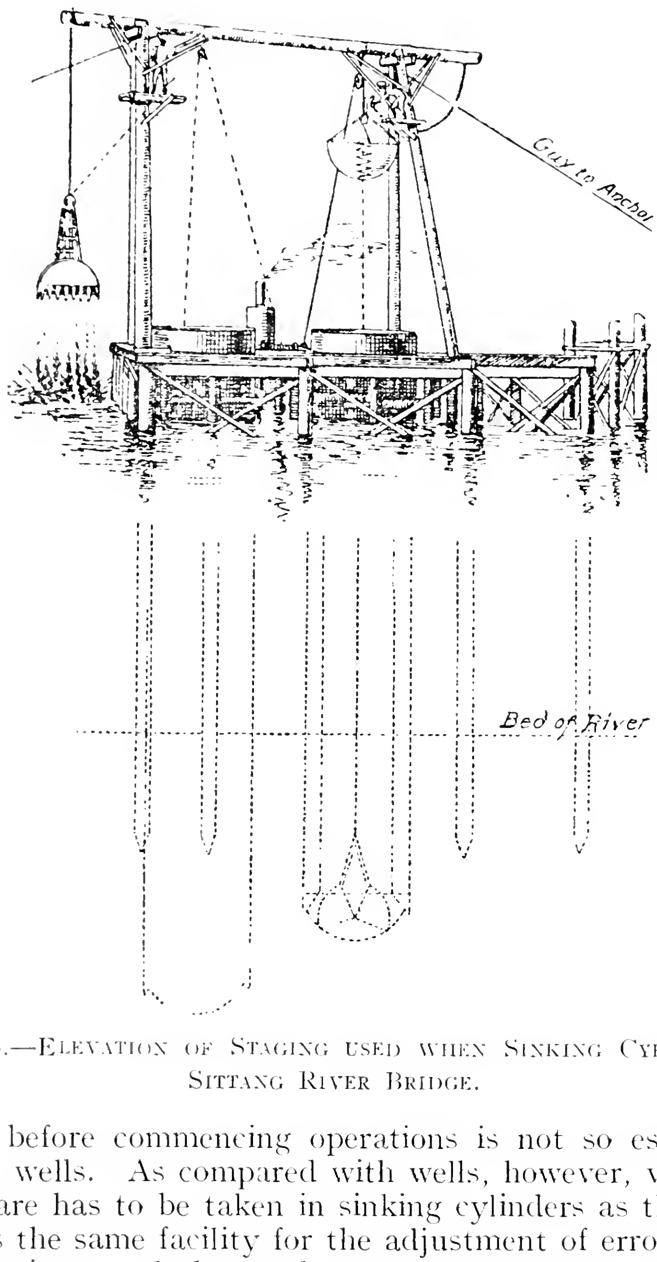


FIG. 5.—ELEVATION OF STAGING USED WHEN SINKING CYLINDERS, SITTANG RIVER BRIDGE.

or stone before commencing operations is not so essential as it is with wells. As compared with wells, however, very much greater care has to be taken in sinking cylinders as there is by no means the same facility for the adjustment of errors. Since prevention is not only better, but very much cheaper, than cure, it is advisable in the first instance to take precautions to prevent the cylinders from being out of position either vertically or otherwise. It was these considerations, together with the example of a certain large bridge where no special precautions had been taken, that led to the adoption of the methods that will now be explained.

Plant for sinking cylinders.—The plant generally used for open dredging is a steam crane on a pontoon. This is an expensive piece of plant however, which is not usually supplied

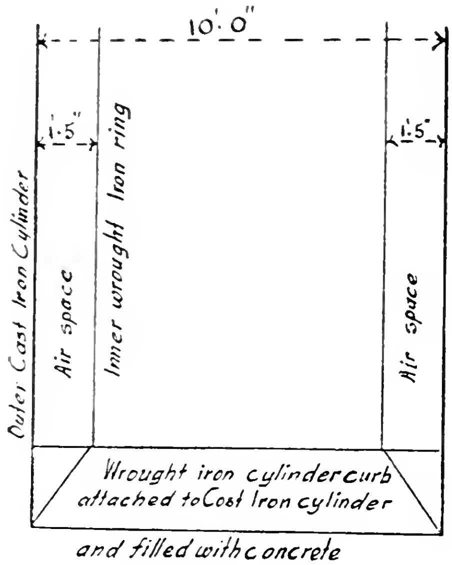


FIG. 6.—SECTION OF A CYLINDER.

to the engineer in the East, where there are no large contractors to take from the Railway Company the heavy burden of capital locked up in plant. The author wishes it to be understood at the outset that a European contractor was not employed and that, therefore, the whole of the detail work of construction devolved upon the engineers concerned. Skilled native labour was employed either departmentally or by various native contractors.

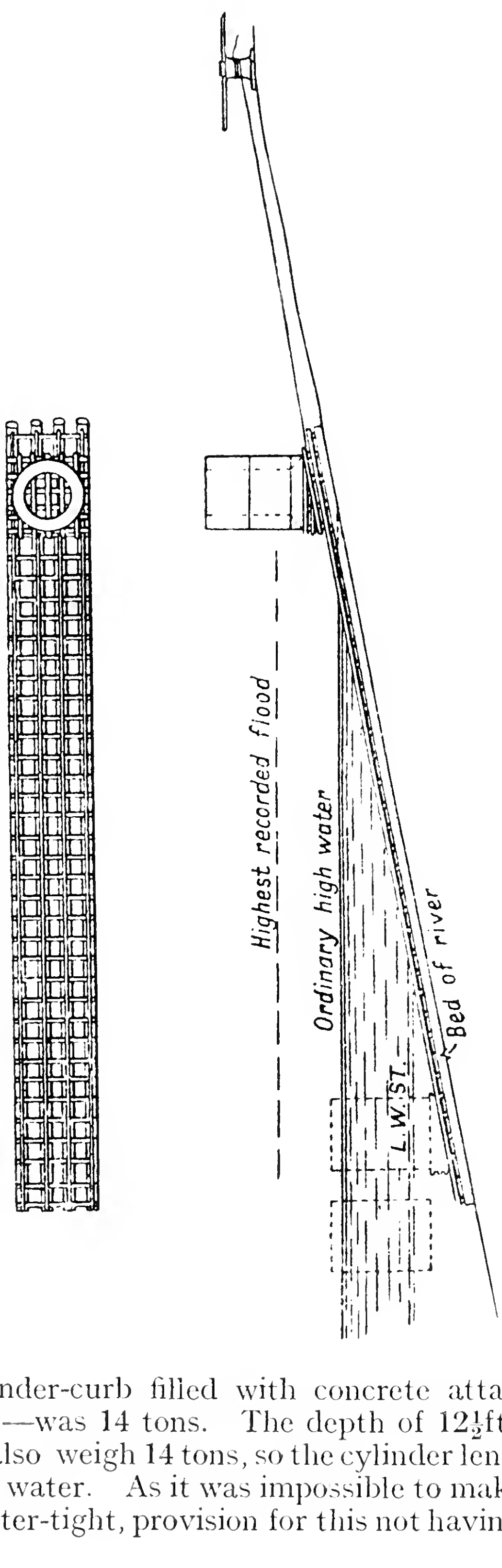
Description of pile staging.—Figs. 4 and 5 show a plan and elevation of the method of piling and bracing with overhead gantry adopted in the sinking of cylinders for the Sittang Bridge; and Figs. 9 and 10 show a similar method adapted for the Indo-Ceylon Railway at Mannar.

It will be seen that the two cylinders are entirely surrounded by a well braced pile staging which also supports a gantry from which the dredger is worked. Figs. 4 and 9 show the staging extended on one or two sides in order to give it greater strength and also to provide working platforms.

In fig. 9 the outer dotted circles mean that no pile is to be driven nearer to the cylinder than 4ft. This is to obviate the danger of the staging piles being undermined by subsidence due to the dredging.

Placing Cylinder in position.—In the Sittang bridge the following scheme was devised for launching and floating out the cylinders. (See Figs. 4 and 6.) A wrought iron inner cylinder of $\frac{3}{16}$in. plate, of the same diameter as the inner edge of the cylinder curb, and of a height varying from 12ft. to 24ft. according to the depth of water at the pier for which it was intended, was riveted to the inner edge of the cylinder curb; thus forming an inner ring, 1ft. 5in. from the outer cylinder.

The air space thus enclosed between the outer cast iron and the inner wrought iron cylinders was sufficient, if everything were thoroughly water-tight, to float a length of either 12ft., 18ft., or 24ft.; the cylinder-curb being first filled with concrete, in order to give stability. The cylinders were in 6ft. lengths, weighing $4\frac{3}{4}$ tons each length, divided into four sections. The calculated weight of one 12ft. length of double cylinders, with



Figs. 7 and 8.—Method of Launching Cylinders.

2ft. deep cylinder-curb filled with concrete attached,—a total height of 14ft.—was 14 tons. The depth of $12\frac{1}{2}$ft. of displaced water would also weigh 14 tons, so the cylinder length would float 1ft. 6in. out of water. As it was impossible to make the cylinder-curbs quite water-tight, provision for this not having been made at

the works, it was considered advisable to hang the cylinder between two barges. This was easily done by means of timber placed across the barges, pumps being kept working in the air space. Figs. 7 and 8 show the method of launching the cylinders. Four large logs were laid along the sloping bed of the river. On these were laid sleepers and four sets of rails. The cylinder was then built up on a cradle made of sleepers and having guides against the edges of the rails. When the tide was at its highest the whole affair was lowered by means of a capstan until it was deep enough in the water to enable the two barges to take it off. It was then got into its position in the staging, and lowered to the bottom by means of 10-ton differential pulleys, as soon as the period of low water had begun. By keeping the air space well pumped out

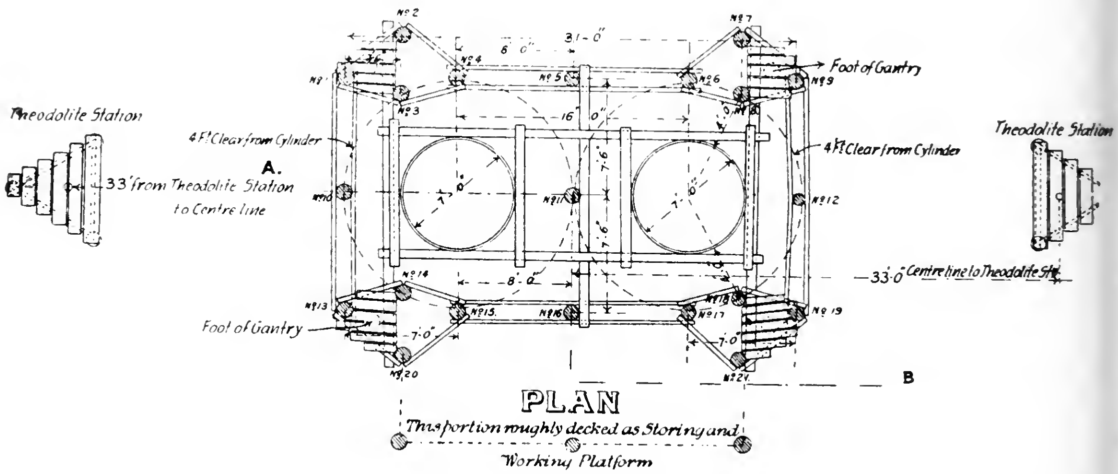


Fig. 9.—Plan of Staging used when Sinking Cylinders, Mannar.

it was not difficult to place the cylinder exactly in position. Much the same procedure was followed with 18ft. and 24ft. lengths. The staging was left incomplete at first, and was completed after the cylinder had been placed in position. At a later period, when some good pontoons were available, it was found easier to build the cylinder 8ft. high at site on top of the pontoon, then let water into the pontoon, thus lowering and removing it, leaving the cylinder hanging from the gantry staging on differential pulleys. It was then lowered and built up until it reached the bottom. In lowering these cylinders the greater part of the dead-weight of the cylinder was counterbalanced by keeping the air space well pumped out, so that he cylinder while being lowered was also partly floating.

After the cylinder had been placed in position the air space

between the outer cast-iron cylinder and the inner wrought-iron one was filled with concrete. Above this, which was also above water level, brick or stone masonry was continued up to the top of the cylinder, thus forming a masonry ring just inside the cylinder 1ft. 5in. thick.

The variation of the tide in the Sittang river during the working season being as much as 10ft., made it necessary that the cylinders should be built either on a floating platform or should themselves be floating, as already described. It has also been explained that after removal of the pontoon the cylinders were lowered and built up until they reached the bottom. This was done by means of four ten-ton differential pulleys. The cylinders in this case were ten feet diameter.

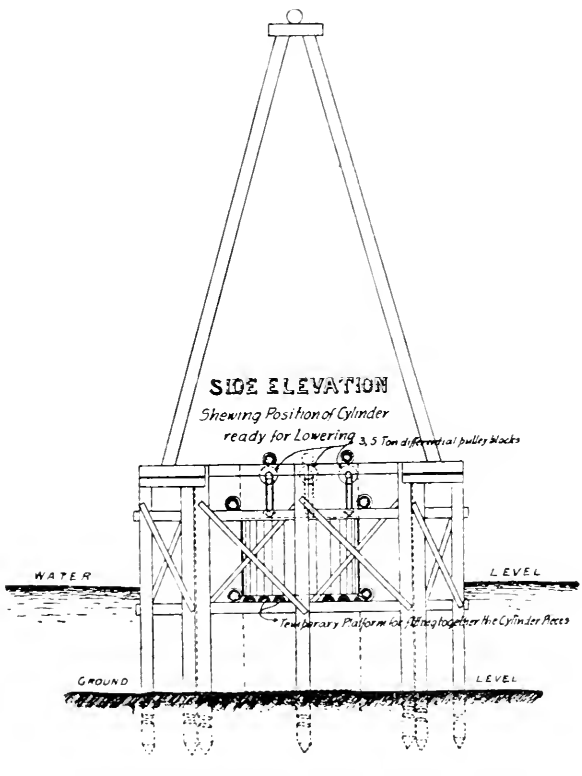


FIG. 10.—SIDE ELEVATION OF STAGING USED WHEN SINKING CYLINDERS, MANNAR.

Mannar Bridges, Ceylon.—In the two bridges over the tidal channels at Mannar, the variation of the tide is not more than three feet at most, and generally not more than two feet.

Instead of floating out or building the cylinders on a floating pontoon, therefore, it was quite possible to build them on a fixed temporary platform. Fig. 10 shows this platform at lowest water level. After building the cylinder on the

platform it was then suspended from temporary cross timbers on top of the piles, the platform was removed and the cylinder lowered to the bottom as already described for the Sittang Bridge.

Keeping Cylinder in Position.—Having got the cylinder into position, it is necessary to keep it so. So far as the author's experience goes the cylinder appears to be always tending to get out of position either horizontally or vertically, or both.

In order to correct this tendency, two sets of four strong logs, one at lowest water level and one at highest convenient level, were arrranged round each cylinder and bolted to the staging. The cylinder was thus held in position in two places, one about 10ft. above the other. These are shown in Figs. 5, 9, 10 and 14. Actual experience has proved that the cylinder has very little chance of shifting its position or getting out of the vertical when thus held. In very deep water (never less than 24ft. in the middle of the Sittang River), any tendency for the cylinder to move the staging was easily counteracted by driving more piles beyond the staging and bracing them up to the main staging; when necessary large wedges were used between the horizontal timbers and the cylinder. Heavy chains were also wrapped round the cylinder and attached with coupling screws to other parts of the staging; or, if the staging were not considered stable enough, the chains were attached to anchors, and tightened up with coupling screws. It is not enough to wait until it can be seen that a cylinder is out of level or position. Its position and level should be constantly tested, so as to detect any tendency to movement before it can be actually seen.

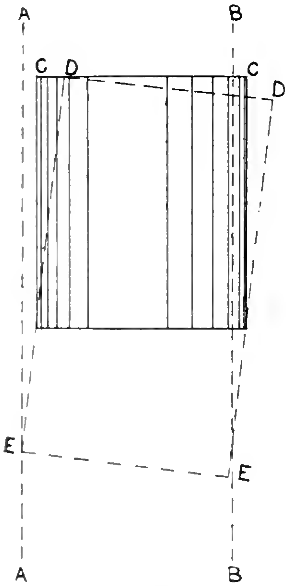


FIG. 11.—METHOD OF CORRECTING POSITION OF CYLINDER.

To correct the position of a cylinder in its early stages the author has found the following method successful (Fig. 11)—Suppose AA and BB to be the correct vertical lines of the cylinder, and suppose it has moved out of its position as *cc*. It may be only 1in. out, but it must be checked at once. The cylinder should be thrown slightly out of the perpendicular as DD. When the sinking is continued the cylinder comes back into its position along the oblique line DE, and when the bottom has reached EE the cylinder can again be brought to the vertical in its true position.

Sinking.—In the deep-water cylinders the total weight on the cutting edges, when ready for dredging, was as much as 100 tons; this very useful weight being chiefly due to the concrete and masonry lining to the cylinder carried to a height of from 30ft. to 40ft. above the river bed. It can readily be imagined that these cylinders did not give much trouble in sinking. Even in laterite (a soft rock) there was no great difficulty in sinking by dredging only. In hard rock divers were employed. The dredging itself was worked by an ordinary steam winch fixed in a barge so that it could be floated from pier to pier as required (see Figs. 4, 5 and 14). In the Sittang Bridge the Bell's dredger was used, a type that is very much to be recommended for such work (invented by the late James R. Bell, M.Inst.C.E., M.S.E.). In Fig. 5 the barge is shown behind the staging so as not to confuse the view.

When the grab is hoisted to the top of the gantry, a man places a hook attached to the outside end of the gantry boom in the link connected with the automatic opening gear of the grab. The position of the man is shown in Fig. 5. The grab on being lowered is then suspended by its opening gear from the outside end of the gantry boom, and so it swings out between the shear legs and opens itself at the same time into the water outside the cylinder. Both the full and the empty grab are shown in Fig. 5, although the two cylinders were never actually both worked at the same time.

Weighting Cylinders.—When a cylinder is insufficiently weighted, either one of two things happens, depending upon whether the dredged material is hard or soft. If the material is *hard* a deep hole may be dredged out below the cutting edge without any corresponding sinkage of the cylinder. This means that the material immediately under the cutting edge has not fallen into the dredge hole. When this occurs dredging must be stopped after 3ft. or 4ft. have been cut below the cutting edge, and more weight must be applied to the cylinder. One very effective way of doing this where it is possible is by pumping the cylinder dry, for which purpose a No. 6 Pulsometer is very useful. This adds to the load the weight of water displaced by the cylinder and lining, and also removes the pressure of water inside the cylinder against the side of the dredged hole, which pressure assists the earth to hold up the cylinder.

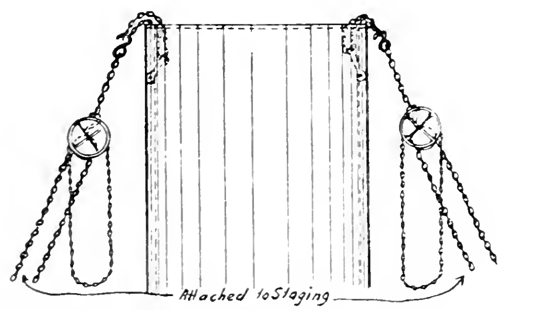


FIG. 12.—METHOD OF WEIGHTING CYLINDERS.

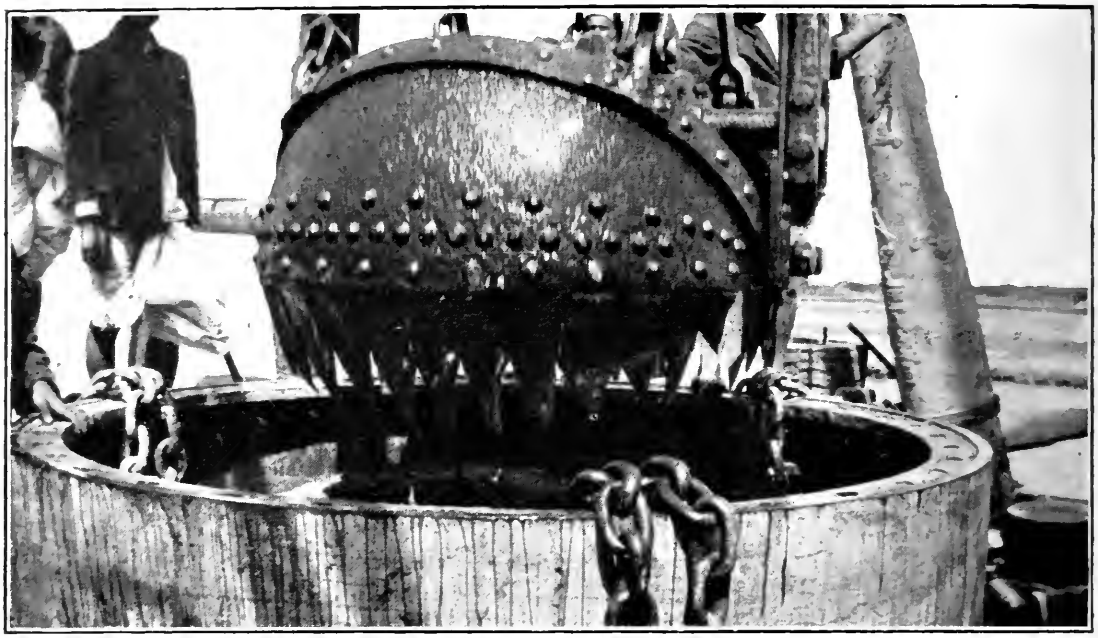


FIG. 13.—GRAB AND TOP OF CYLINDER, SHEWING CHAINS FOR WEIGHTING CYLINDER.

Pumping dry, if it be practicable, has this added advantage over any other method of weighting: even if the cylinder does not sink at once it is easy to make it do so by sending men down to cut away the support.

It often happens, however, that long before the cylinder is pumped dry the pressure of water outside is too much for the nature of the earth, and then what is known as "blowing" occurs, perhaps only along the line of a softer or less impervious material. In that case we have arrived at the same results as we should have done in dredging through a *soft* material with an insufficiently weighted cylinder. This means that instead of the cylinder sinking by its own weight and occupying the dredged hole, the soft earth from outside falls or blows in to occupy the space thus created. It is useless to go on either pumping or dredging under these conditions, for the only result is the dredging of material from outside the cylinder, thus greatly imperilling the safety of the staging. Sometimes it is even necessary to fill in the hole outside the cylinder. More weight is required on the cylinder to cause it to sink as fast as it is dredged.

The usual method of weighting cylinders is by piling up rails, and they certainly give the best effect for their size. This, however, is a tedious and expensive process, and often before sufficient weight is applied the height of the cylinder is so much increased that there is no room for the grab to swing out to empty itself (see Fig. 5). The weight is also very top heavy, and so increases

the tendency of the cylinder to sink sideways, and moreover the rails have all to be removed whenever it becomes necessary to put on more cylinder lengths.

These considerations show how very effective it is to have as much weight as possible incorporated with the cylinder itself, as was done in this case by means of a concrete or masonry lining.

Another method of weighting cylinders when no rails were available was practised at Mannar (see Figs. 12 and 13). Three 5 ton differential pulleys were attached at one end to the pile staging and at the other end to shackles fixed in the cylinder bolt holes. A pull of about 15 tons could be applied in this way. The result has frequently been most effective. On the first occasion on which it was applied a cylinder that had hung up for some days was sunk 8 ft. in one day by this method and dredging.

Abutments.—Figs. 2 and 3 are completion drawings of the whole bridge, and show the nature of the material through which the cylinders were sunk and finally founded on. The levels given for the foundations are minus quantities below mean sea level. U denotes the up-stream cylinder and D the down-stream cylinder.

The east bank of the river is a laterite cliff about 80ft. high, so that, as the drawing shows, an ordinary open foundation fulfilled all requirements for this abutment. The west bank is on the edge of an extensive alluvial plain, and, being on dry land during the working season, it was decided, for reasons already given generally, to use an ordinary 22ft. outer diameter brick well for the foundation of this abutment. The sides of this well were built of 6ft. thick brickwork, leaving an opening of 10ft. diameter for dredging purposes, afterwards filled in with sand and concrete as shown. For dredging this well a large Scotch crane was used, but even with this great weight of brickwork and although the material through which the well was sunk was comparatively soft, the skin friction held up the well considerably so that much "blowing" occurred.

Depth of Cylinder Foundations.—It will be noticed that the cylinders from the east bank were sunk down to the laterite as far as pier No. 7. Pier No. 1 was sunk 12ft. into laterite rock only, this depth being necessary to obtain sufficient stability for the height. One of these cylinders was kept dry with a 6in. centrifugal pump, but the other had to be worked by divers. Piers Nos. 2 to 7 gave little real trouble. When the cylinders got well into the laterite, which was of a comparatively soft nature, they became dry by the operation of dredging.

Piers Nos. 8, 9, and 10, reached the requisite depth of 55½ft. below bed level without striking the laterite and were, therefore, finished on the coarse sand. It was considered advisable to go

to this depth even in such a good material as coarse sand to avoid all danger from scour in abnormal floods.

Great flood of 1909.—In this connection some reference to the great flood that occurred in 1909 may be of interest. A reference to the map (p. 252) shows the Pagaing Bund, about 15 miles long, running from the main line railway embankment to Myitkyo at the junction of the Pegu-Sittang Canal with the Sittang river. This was an embankment made at the time of the canal construction in order to keep back the annual Sittang flood from flooding the canal, and incidentally it brought under cultivation a large area of land which was previously too much subject to floods for cultivation. In September, 1909, this bund burst. The water flooded the whole of the country from Pegu to the Sittang river up to the new railway embankment and all the water that could not find room through the smaller bridges came back into the Sittang River above the bridge. Naturally this was a source of great anxiety to the railway engineers and an engineer was kept for days together taking levels on the bridge in order to ascertain if any of the piers were sinking. Fortunately the bridge stood this severe test very well. Fig. 19 shows one of the cast iron plates fixed at the top of each cylinder. These show the depth and the nature of the foundations in each case, thus IC = Iron Cylinder ;

R L – B F 113.0 = Rail level to bottom of foundations, 113ft.

R L – T F 55.5 = Rail level to top of foundations (or bed level) 55½ft.

L 9 = Laterite 9ft.

This carries out the order of the Government of India for all bridges other than culverts and it enables the man on the spot to ascertain at once the extent of the danger in such abnormal times as have been described instead of having to hunt it up from some head office records. The author has had some experience of hunting up these records for the purpose of fixing these plates on old bridges and has found that in some cases the information is unobtainable. At the present time no bridge in India is considered completed until these plates have been fixed.

Temporary Bridge.—It will be noticed (Figs. 4 and 14) that for the purposes of construction a partial temporary bridge was constructed which greatly facilitated the carriage and stacking of materials. A great part of this was carried away by the flood of 1906, but by that time it had almost served its purpose. The triangular groups of piles (Fig. 9) on each side of the pier stagings are theodolite stations for squaring off each pair of cylinders. Permanent marks were fixed on these so that a wire could always be stretched across to test the positions of the cylinders.

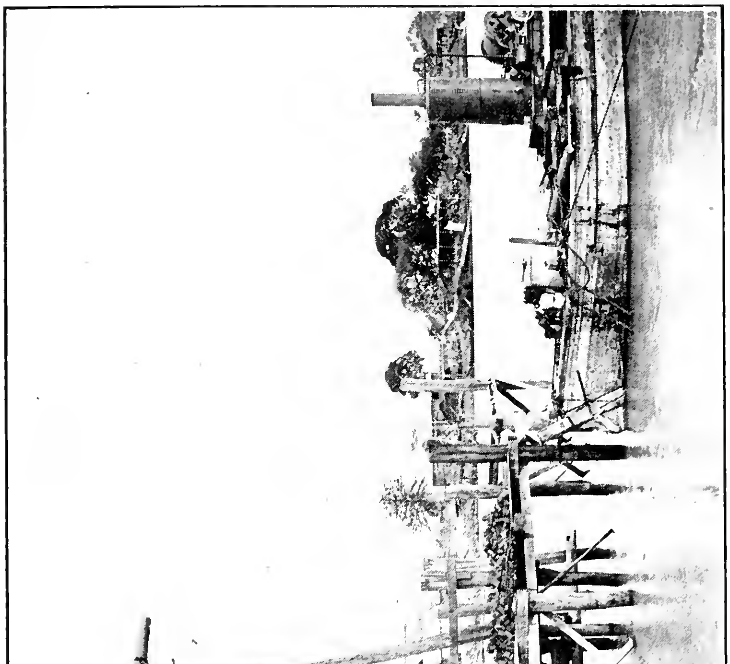


FIG. 14.—PIER STAGING.

Concreting.—The cylinders were filled with a mixture of concrete of 10 parts stone, 5 parts sand, and 2 parts cement. The author was fortunate in having the use, for the purpose of floating out the concrete, of some iron pontoons from 40 to 60 ft. long by 10ft. wide. These were intended for eventual use as part of the landing stage for transport of passengers and goods over the Salween River from Martaban to Moulmein. The concrete was loaded on to the pontoons on shore and was then floated out to the site of each pier and filled in to each as soon as the sinking was completed.

Material for concrete, masonry, and brickwork.—All the stone for concrete was taken from the neighbouring hills and was boated down a tributary river. Some of this was also available for masonry in the lining but, as this is always a slow process both in the getting and working, the author at the very beginning of the work made arrangements for the manufacture of a large quantity of bricks on each side of the river by a native contractor. This arrangement of a double supply of material was fully justified in the result, for from one cause or another one always has to expect temporary failures of supply in the East, and nothing is more disheartening to all concerned, since these failures affect all classes of labour on a work of this magnitude.

Transport.—One of the earliest problems for consideration was that of the transport, from Rangoon to the site, of some 3,000 tons of steel and cast-iron and plant. The cylinder sections and steelwork all had to be sent on as soon as they were landed in Rangoon from England, for the stacking ground at Rangoon was very limited.

Owing to the tidal bore in the estuary of the Sittang River that route was impossible (p. 252) ; and it was for this reason that the Pegu-Sittang Canal existed. The canal route was, therefore, used. There being no contractor able to undertake the work, three steam launches and a number of barges were purchased and the work went on very well until one of the locks on the canal fell in and delayed the work for some three months. Had this not occurred, however, as it subsequently appeared, the work would have been delayed in any case because the cylinders were being sunk into the river faster than they were coming out from home, so that the delay in the canal allowed the manufacturers to gain time on the construction.

For landing stores from the barges a dock was constructed at Sittang out of the laterite, the sides of which held up fairly satisfactorily without any retaining walls for as long as required. A small steam winch attached to a Scotch crane did all the work of unloading. The dock, however, was only available in the flood season and for the dry season a small jetty was constructed. In connection with this a proper stacking ground with various

sidings had to be arranged for connecting the dock and jetty with the store shed, workshop, temporary bridge, and eventually (up a grade of 1 in 50) with the main line of the railway towards Martaban.

Not only were materials for the Sittang Bridge landed, but rails, sleepers, girders, trucks and locomotives were either brought direct or transported across the river and landed at this depôt for other parts of the railway.

Girder erecting.—Girder erecting began as soon as a pair of piers was ready to receive them.

Work began from both ends of the bridge on stagings built on piles, except number eleven span where no piles were necessary. The girders could be conveniently built only one span at a time at each end. As soon as a span was completed the stagings were removed to the next span. The piles necessary for the middle spans, however, would have had to be over 40ft. long, at which height without bracing they are not only very unsteady but, as the time for this work was expected to run into the rainy season, were considered too dangerous to withstand the flood, coupled with the fact that there would also be other stagings obstructing the river. It was also advisable to gain time by erecting more than two spans at once. It was, therefore, decided to float out the fourth and fifth spans. This as is well-known has often been done at a low level and the girders jacked up as the masonry work proceeds. The cylinders being in six feet lengths put this method out of the question. It was, therefore, decided to float out complete spans at full height. It was for this purpose that the iron pontoons already referred to were brought to Sittang.

Floating Out Girders.—The design of the complete landing stage was composed of 7 pontoons of which 4 were 40ft. × 10ft. and 3 were 60ft. × 10ft., with a girder superstructure arranged to connect the pontoons and to carry a wooden platform. This arrangement, however, was found by calculation to be insufficient to carry the complete span without too much immersion. The complete 150ft. span weighed 113 tons, but this was reduced to about 100 tons by omitting some of the overhead cross bracing and other parts. By packing the pontoons absolutely close together it was found possible to get 9 pontoons underneath their own girders, which gave the requisite floating area with the addition of a large flat attached, the whole being 100ft. long by an average of about 57 ft. wide.

On this floating structure a strong staging was built up. Fig. 15 shows the method of building the girders on shore and transferring them to the pontoon. A staging of the same type as that used at bridge site was built on the river bank up to the same level as the tops of the bridge piers. From this staging two jetties

FIG. 15.—GIRDER ABOUT TO BE LIFTED FROM TROLLIES.

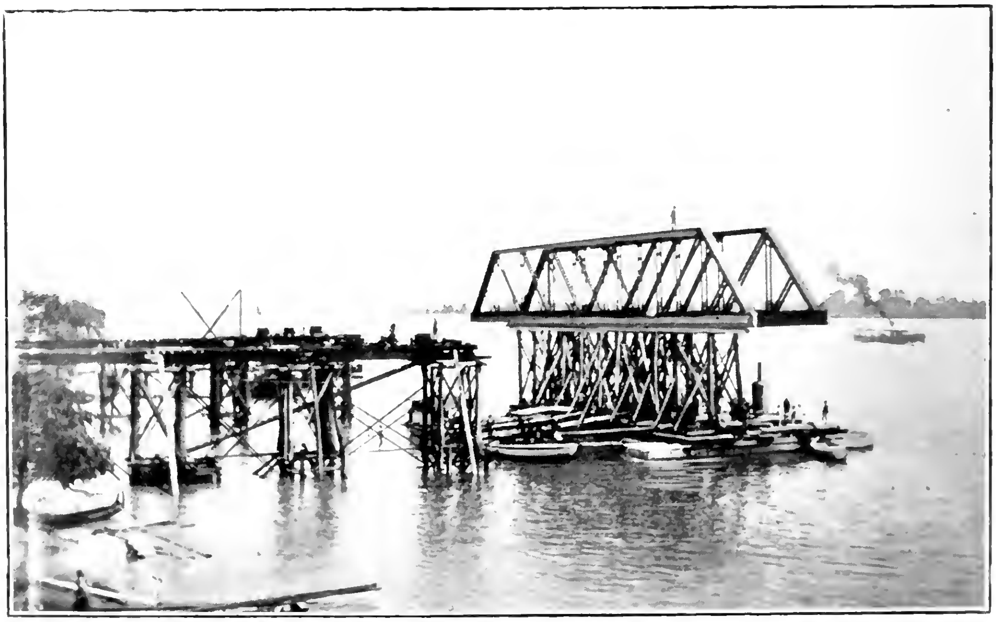


FIG. 16.—GIRDER TRANSFERRED TO PONTOON.

were run out to deep water, composed of three spans of spare 20ft. girders on piles. Rails being laid on these, the 150ft. span girders were jacked up on to some very strong girder trollies, four of which the author was fortunate enough to find in the Rangoon Railway Stores. When all was ready the four trollies with their 100 tons weight were hauled out to the end of the jetties by means of crab winches on the shore. Everything was timed to be ready so as to take advantage of a rising tide for lifting the girders off the trollies. This all worked out exactly as intended. Fig. 15 shows the girders just about to be lifted from the trollies, and Fig. 16 shows the girders transferred to the pontoon and floated away from the jetty. It had originally been intended to use steam launches for hauling, but it was found that the pontoon was too unwieldy and the square sides offered too much resistance. A set of anchors had, therefore, been placed in midstream, and another set beyond the vacant span in the bridge. The pontoon was easily moved to its position by warping or hauling on these anchors.

Fig. 17 shows the span floating in mid-stream. It took about two hours after leaving the jetties before the girders were brought into position. Men standing on the top of the cylinders were easily able to bring the ends of the girders into position. Water was then let into the pontoons by means of cocks already provided for the purpose, and while the girders were lowered the men on the top of the piers guided them into position. Though it was comparatively easy to lower the girders into an approximately correct position it was too delicate an operation to place them direct on to their saddles and rollers. This work was carried out later by means of hydraulic jacks. Fig. 18 shows the span in position, the pontoon not yet removed.

The total depth of the girders was 20ft., and they overhung 40ft. on each side of the staging. This overhang reversed the compressive and tension stresses and this caused a slight bending in the last fall tension bars. This, however, was of no consequence, and the reversing of the stresses had no other effect.

This span No. 4 was floated out on the 30th May, 1907. The first cylinder had been placed in position for starting sinking in October, 1905. Preliminary operations had been carried on since April of that year, but owing to the monsoon the work on the permanent structure could not be started earlier. It was unfortunate that in 1907 the monsoon started exceptionally early, viz., on May 4th, when 21in. of rain fell in 24 hours. It was not expected that the river would be in flood until the middle of June. Great efforts, therefore, had to be made to remove all stagings from the river as soon as the girders built upon them were able to sustain themselves. This was effected just in time. Work on the last span to be built and floated out was begun on 31st May,

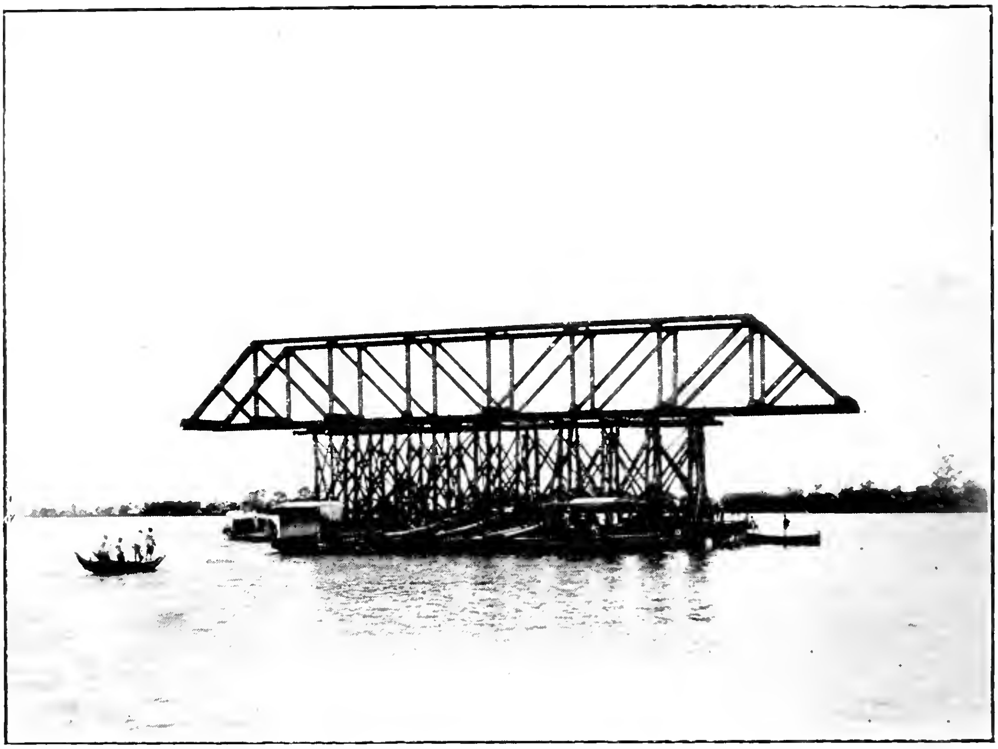


FIG. 17.—SPAN FLOATING IN MIDSTREAM.

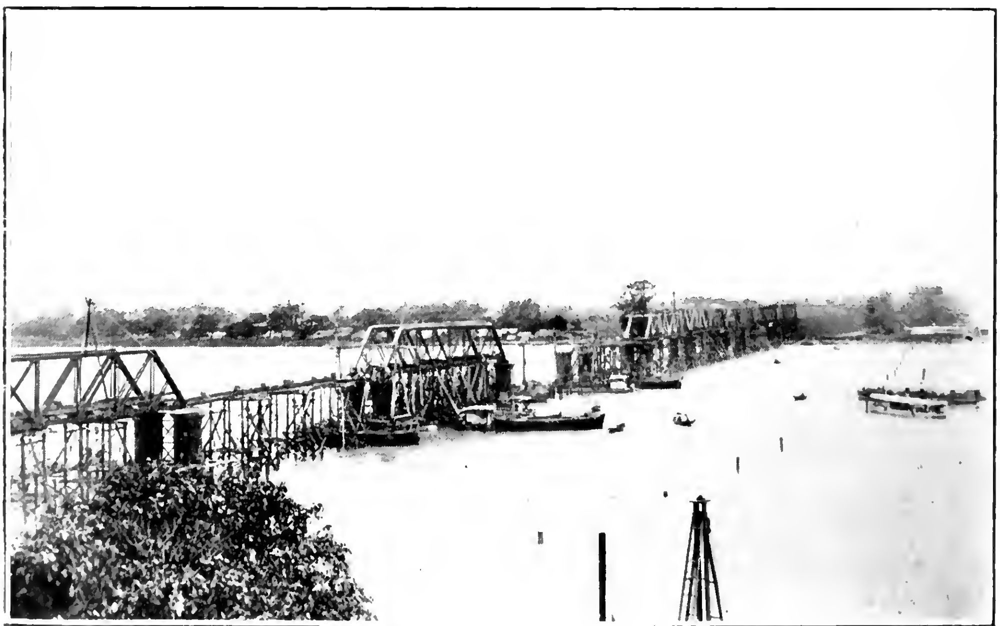


FIG. 18.—SPAN IN POSITION BEFORE REMOVAL OF PONTOON.

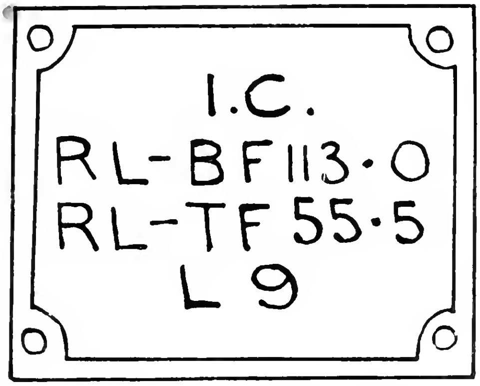


FIG. 19.—CAST-IRON TABLET SHOWING DEPTH AND NATURE OF FOUNDATION.

but, owing to a serious outbreak of cholera and continuous heavy rain it was not ready for floating out until June 30th. By that time the river was in full flood, and was 8ft. higher than on May 30th. The girders had therefore to be jacked up 8ft. on the jetties before the pontoon could be brought under them, and had to be placed on the bridge 8ft. too high. This was easier than cutting down the floating staging.

Although this last span had to be hauled up against the flood, no great difficulty was experienced. The only difficulty was in removing the pontoon from the bridge as the water was rising instead of falling. As soon as it had been removed, a tremendous squall broke over it, and as it was after nightfall there was some difficulty and danger in returning the unwieldy craft to her anchorage.

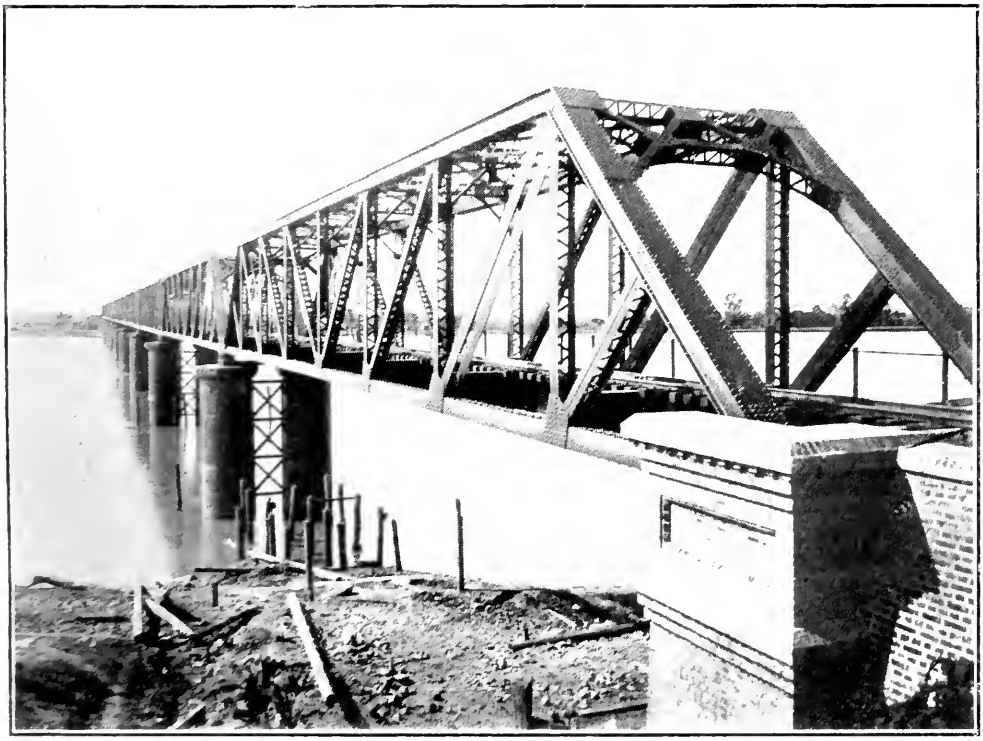


FIG. 20.—VIEW OF COMPLETED BRIDGE.

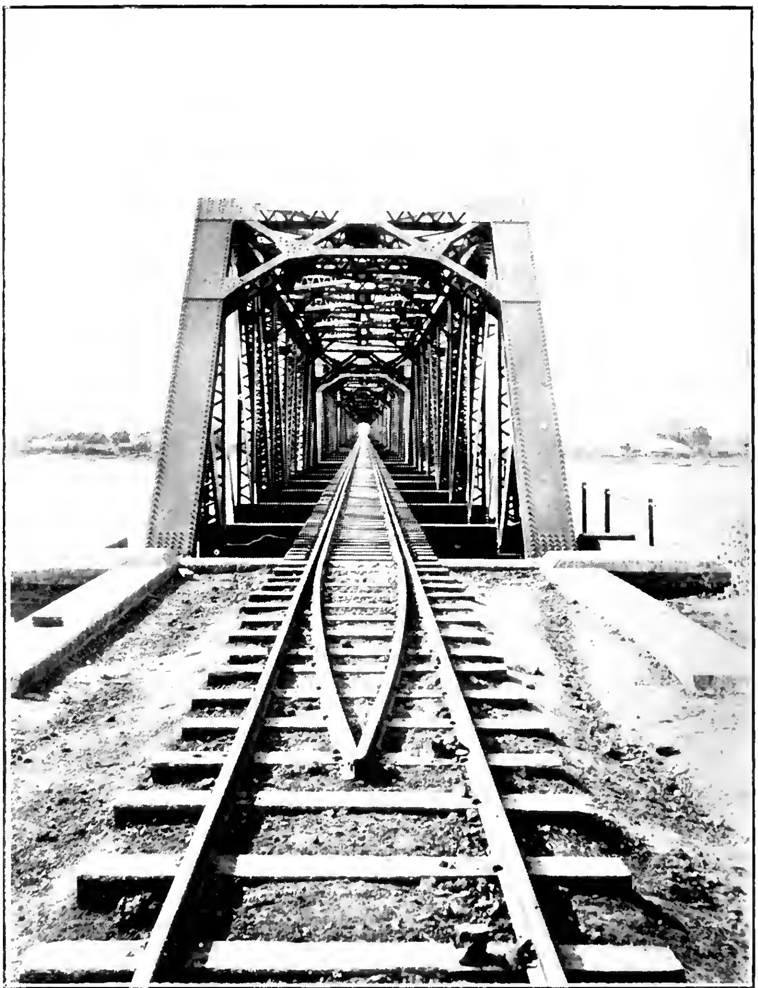


FIG. 21.—VIEW ALONG COMPLETED BRIDGE.

Figs. 20 and 21 are views of the completed bridge.

On August 4th, 1907, one year and ten months after the first cylinder was put into position, the first train passed over the bridge, which was opened for goods traffic the following day.

The Government test of the girders, on September 24th, 1907, showed that although they were 20ft. deep, the side oscillation at the top, while the test train was running at 20 miles per hour, was only $\frac{3}{8}$in. This speaks well for the native riveters.

Accidents.—Only one fatal accident occurred, and was due to a man falling into a cylinder at night and being drowned. One man fell 40ft. to the ground when girder erecting, but was uninjured.

Changes in the River Sittang.—Referring to map, Fig. 1, the

author wrote a short account of this river in the *Engineer*, of June 4th, 1909, as follows :—

" At some time during recent years the Government of Burma, in order to drain the land, either assisted or allowed the villagers to construct a small 6ft. wide canal from a point somewhere between C and D to D.

" The action of the bore began to open out the mouth of this oanal and the water spread over the land and in returning opened cut the canal in all directions."

To make a long story short, the canal widened itself in less than two years between 1903 and 1905 to a river three or four hundred feet wide through which the flood waters of the Sittang flowed. The author then wrote : " The position now is that for three or four months of the year there is a continual stream of water running through the short cut along the line, A.B.C.D. which is, of course, all the while deepening and widening its channel, and it is only a matter of time for the slower and longer route to be abandoned in favour of the short cut."

This meant that the river would abandon 45 miles of its length and take a new course of only 3 miles in length. The difference of level over this 3 miles was 5ft. so that the average gradient would then be $1\frac{2}{3}$ft. per mile instead of $1\frac{1}{3}$ins. per mile, which would certainly increase the velocity through the bridge for a time.

It was therefore decided in 1906 that a Bell's guide bank would be necessary on the West bank of the bridge to prevent the river from taking a new course, and a design for this was prepared and sanctioned although not carried out until some years later. The author has since learnt that the short cut has now finally established itself and that the tidal bore now runs up to the bridge. This result having been foreseen and provided for, no harm has been done either to the river banks or the bridge.

Cost.—The total cost of the bridge exclusive of the guide bank was about £66,000.

Engineers.—The consulting engineers responsible for the design of the bridge were Messrs. Rendel and Robertson of Westminster, and the chief construction engineer of Burma Railways responsible for the carrying out of this work was Mr. G. Mills, M.Inst.C.E.

Conclusion.—In conclusion the author acknowledges thanks to the editor of the *Engineer* for permission to reproduce some of the drawings, &c., which appeared in that paper in its issues of June 4th and 18th, 1909.

Discussion.

The **President** said that he had to propose a very hearty vote of thanks to the author for his paper. A description of works which the author had had personal charge was always peculiarly valuable, and it was a great advantage to have the engineer of the work present and to be able to ask him questions. He had received letters from members of the Society and others who were unable to attend the present meeting owing to the fact that they were serving their King and country in the Army or Navy during the war. One letter had been passed by the censor, and came from H.M.S. "Illustrious," but from what part of the world it had come was unknown. The writers of these letters, if they had been present would, he knew, have joined in the vote of thanks to the author which he was proposing.

The vote of thanks was unanimously agreed to.

Mr. Ernest Benedict said that the work described was carried out in a very bold way, but the risks were successfully run, and nothing succeeded like success. The time taken was wonderfully short, considering everything, and he thought that the engineers deserved great credit for what they did.

With regard to the twin wells, it had always appeared to him that it was a mistake, in Indian rivers where the bed was very unstable (in this case the bed did not seem to be so unstable as some were), to have anything but the circular pier, because if what they might call a half tide or half water stream began to wobble about, as it always did, the twin cylinders might form a great obstruction ; in fact, some of the low water streams really went in and out of the bridges. Consequently, instead of having the usual scour in one place, one had it all round the cylinder, and it was very dangerous. That was why he had always advocated single cylinders. They were rather more awkward to handle, but still, seeing that wells of as much as 20ft. in diameter, one of which was mentioned in the paper, had been sunk from time immemorial in India by the natives with native appliances, there seemed to be no difficulty, or there should be none, in sinking large piers.

With regard to double octagonal piers, curiously enough, the present Sir John Jackson in 1877 used the same design for the walls of what was now called the Queen's Dock, in Glasgow. He also sank octagonals, not in pairs, but in threes, so that one fitted into the other, and the foundations of the dock walls were all dredged out by enormous gantries built up over them.

Another thing that had struck him was the very easy way in which the cylinders dealt with in the paper were guided. He had had to do with cylinders, and he had found it an exceedingly

difficult thing to keep them in position ; but in the case dealt with they apparently had only to be tilted a little bit and they did exactly what was wanted. When so tilted they went exactly to the right place, but he had always found that if they were tilted at all they went with a run long past the place where they were wanted. The cylinders described seemed to be very amenable, and he wished that all were like that.

The paper said : " It was impossible to make the cylinder-curbs quite watertight, provision for this not having been made at the works." That was a most extraordinary statement. Surely they could have caulked the iron joints.

With regard to weighting, the late Sir William Arroll, for the Caledonian bridge at Glasgow, sank a very large cylinder on the quay, and there was enormous friction. He had some lead castings made to fit the inside of the cylinder and to rest on the inside flanges. They were so designed that their centres of gravity were placed in such a way that they had no tendency to tilt up and fall down the cylinder, and the castings were not fastened in any way. By means of these he lined the cylinder with a good thickness of these solid lead castings all the way up. They could imagine what the weight was. There was no difficulty in sinking the cylinders, and the space in the centre was left open. When the lead was taken out its value had greatly increased, so that Sir William actually got all his weighting done for nothing, and, in fact, gained by it.

With regard to finding out the position of the piers, at the Gorai Bridge in Lower Bengal, from and at right angles to the centre line, a thousand feet length was very carefully measured, along the high bank of the river. At the further end of the 1,000ft. line an observation tower was put up, and 100ft. from it was laid down what might be called a drawing table, made of logs of wood planed very true and a thin line was scribed on it parallel to the centre line of the bridge. Their cylinders were " all over the shop," so that it was very desirable to find out accurately what their position was. A survey pin was stuck in the centre of each cylinder ; like the Sittang bridge each pair of cylinders had a girder connecting them.

They marked the centre line on these girders and then measured the distance from the centre line to each centre pin. Then on the drawing-table they marked the angles from each pier, and, knowing what the distance was, they drew short lines parallel to the centre line, at a tenth of the real distance and intersecting the angle lines, and put in pins at the intersections. The tower was a high one and a 3ft. theodolite was used. By means of the pins on the table, they got the exact position of the centre of each cylinder. They could measure the distance to the one-hundredth part of an inch on the table, which would represent

the tenth part of an inch on the piers. When they floated the girders across, he was on one pier, and Sir Bradford Leslie was on the other. They had marked on the cylinders where they wanted the girders to come as ascertained by means of the table. He (Mr. Benedict) would call out the distance the girders needed to be moved, and they were moved accordingly.

Another respect in which the engineers of the Sittang bridge were very bold was in sending men down under the cutting edge. That was distinctly dangerous, because if a blow occurred at the time the man would be buried.

Then the author said that it was easy to get the cylinders down. "In very deep water (never less than 24 ft. in the middle of the Sittang River), any tendency for the cylinder to move the staging was easily counteracted by driving more piles beyond the staging and bracing them up to the main staging; and when necessary large wedges were used between the horizontal timbers and the cylinders." That struck him as rather adding to the friction. On the Sittang bridge they had only 24 ft. leverage in order to pull the cylinders about, but on the Gorai bridge they had 90 ft. of water, and still they had some difficulty in guiding them.

With regard to pumping the cylinders dry, that added to the weight very much, but at the Gorai bridge the lower length of the cylinder that was to go in the ground was 14 ft. in diameter, and the rest was 10 ft., exactly like Charing Cross bridge. There was a conical piece between the 10 ft. and the 14 ft., a false bottom was fixed during the sinking, and when the cylinders were pumped out they got the weight of water on the 2 ft. ring all round, which added very much to the effective weight of the cylinder.

One question that he wished to ask was with regard to floating this unwieldy affair across the river. The author said in a very casual sort of way that they put some anchors out, and there was no difficulty. The same thing was done at the Gorai bridge, but they did not find it quite such an easy job as it appeared to be from the paper; not only that, but, just as they got the floating girder in the middle of the span, a fleet of heavy country boats came down, which would have snapped their hawsers and taken the whole thing down the stream if they had not motioned the craft out of the way; luckily they got through a clear span just in time.

In one photograph the theodolite stage was shown very much out of the water. It struck him that the staging must have been shaky. Perhaps it did not matter, but he did not think that observations taken from such an upright and lanky staging would be very exact.

He wished to thank the author for showing what could be

done in India with nothing but native labour, which was not always reliable. He would give an instance of that. They had lifted right up to the surface a cylinder which had toppled over and was half full of sand, and Sir Bradford Leslie said to him. " Go down and see if they have the bolts tight on the bollards." To these were attached the chains on which the cylinder was slung. A man had been sent down to screw them up if necessary, and he (the speaker) went down and found that the man was unscrewing the bolts instead of screwing them up. The whole thing might have gone down again after three months' labour. That was the sort of trouble that engineers had to look out for in India.

Mr. G. Mills said, with regard to the danger of a " blow " when sinking cylinders, that in the case of the Sittang bridge where the man was sent down underneath the cutting edge there was no sand to blow. One edge was on a very hard piece of rock, and the rest in laterite.

Mr. E. Benedict said that natives were very clever in getting their feet or their hands or some other part of their bodies under the cutting edge.

Mr. G. Mills said that he had had some experience in the sinking of twin cylinders. They were most difficult to deal with, and he was very much surprised at the successful way in which Mr. Buckle managed the sinking of them. They had the diameter raised from 8 ft. to 10 ft. He thought that a single cylinder would have been much better. With regard to the floating out, he thought that there was no other way of doing it, partly because there was 26 feet depth of water most of the way across the river and because there was a bore which came 11 ft. high for a tremendous run up the river. Those who had never seen such a bore would hardly believe the effect. A regiment of Madras Infantry were coming up the river, and the boatmen assured the Colonel that the bore would come at about that hour and that he must land and get the boat under shelter. The Colonel said, " Oh, nonsense, it is nothing at all," and the result was that all the men were drowned, and the cemetery in which they were buried was at the side of the Sittang bridge.

Mr. Benedict said that he was not surprised at the floating out, but he was surprised at the ease with which it was done.

Mr. G. Mills said that there was a period when the water was fairly slack when the tide rose. Twice a month the water was fairly steady. There was not much boat traffic up and down the

Sittang River on account of the bore. He did not know how Mr. Buckle managed the stagings for the theodolites, but they seemed to be very fairly firm, although they were in such deep water. He understood that the author had them braced. He must say that he thought that the bridge was a very difficult one to build, on account of the deep water, and they were much troubled with regard to getting material up the Pegu-Sittang Canal because it silted up at the very time when material was most wanted. Then, just as the bridge was nearing completion, they suddenly got orders to shut the work down, as there was no more money. To stop the work in a state like that was quite impossible; the bridge might have stood by itself, but if it had been left half finished it would probably have become very difficult to go on with it again, and a good deal of it would have been very seriously damaged in the interval. Therefore, they took what he thought was a more serious risk and went on without money. Luckily, at the end of the financial year, a little money was available, and they were able to pay. It would have cost a very great deal more if the work had been stopped, because the bridge would not have been finished that year, the line would not have been opened, they would not have been able to get the trains through Martaban, and, therefore, the revenue on the line would have been lost. The cost of the bridge was rather heavy, but labour was very expensive in Burma—most of it double of what it was in India—as it all had to be imported. The cost of the bridge worked out to about 560 rupees a foot, and about 4·12 rupees per square foot of side area. He thought that the bridge was extremely accurate when it was finished.

Mr. H. J. Fereday said that he must express the regret of Mr. F. Palmer at not being able to be present. The author referred to the general practice of sinking wells in India by open dredging. It was really remarkable, with the difficulties that had to be met, how quickly and accurately the work was done. As the author said, it was astonishing that other means should be adopted for well sinking when they could be avoided. He had recently been getting out a scheme for the cylinders of a bridge in which it had been necessary to comply with three conditions. One was by sinking them with open dredging only; another was the application of air compression if required; and another was by air compression entirely. He had come to the conclusion that the extra plant for applying air compression, (which indeed the engineer on the spot hoped never to require) was seldom justified.

The author had referred to the Lower Ganges bridge. The sixteen piers, all of which were now in place, had been sunk by the method which the author had adopted in the Sittang bridge.

The cylinders were, of course, very much larger and oval in section, but they were sunk 150 ft. below bed level, and some of them he believed much lower than that. He believed that the foundations of that bridge were the deepest foundations of their type in the world.

The author had referred to the weighting of cylinders with tackle. The paper did not say, but he supposed that, in that particular bridge, notwithstanding the cylinders being rather small as cylinders went, it was never necessary really to weight them at all, because the tackle applied in this case was so small, and much below what would actually be required to help the sinking of them. He thought that the author mentioned 15 tons. Had the author made any test, during the progress of the work, of the amount of skin friction developed, and what was the pressure per square foot on the foundations when the bridge was finished, skin friction and buoyancy not being considered ?

The method of marking piers was very good and should have been adopted before, as it was often difficult to find, either on the site or in the office, the depths to which cylinders had been sunk.

Mr. Mills had referred to the cost of the bridge, which appeared to be £66,000. He did not quite know what the cost of steelwork erected in Burma would be at that time, but taking it at £15 a ton the cost of the steelwork came to about £19,000, which was a much smaller proportion of the total cost of £66,000, than one would expect. The cost of a span should be about equal to the cost of a pier, but in the case in point the piers cost very considerably more than twice the cost of the spans.

Mr. Buckle's paper formed a link between the man on the spot and the consulting engineers in Westminster. As a matter of fact they did not hear enough about the erection of bridges. They often sent out steel work to India, Burma and elsewhere, for cylinders, curbs and bridges and they never heard again of them. Whether that was a compliment or not, he would leave the meeting to judge.

Mr. J. W. Wilson suggested to the last speaker that the Hawkesbury bridge cylinders were even deeper than those he had mentioned, viz., 162 ft. He should like to ask Mr. Benedict whether he could give them the approximate dimensions of the portion of the cylinder which Sir William Arroll sank with lead, so that they might be able to form an idea of what the mass of lead represented, and also tell them how the mass was attached at the time in order to produce the sinking effect.

Mr. Benedict said that it was not attached at all ; it rested on the inside flanges. He fancied that the cylinder was about

14 ft. in diameter, and these segments were probably about 6 ft. long. There were lead segments cast on purpose.

Mr. J. W. Wilson said they all would probably have noticed that the girders mentioned in the paper had a considerable depth compared with their span. From centre to centre the length was 160 ft., and the depth was 20 ft. The author had alluded to this fact in reference to the test of the side vibration of the girders. He (Mr. Wilson) thought that it opened up an interesting question for the bridge engineer. He had lately been inspecting some drawings of new bridge work in Canada where much the same proportions were adopted. Perhaps the author could inform them what deflection tests might have shewn, for it was interesting to know to what extent the depth of the girders should be taken so as to reduce the weight without undue introduction of light sections.

The idea that plates with information should be placed upon engineering work was an excellent one, not only with regard to bridge work, but almost any kind of work which was hidden. In one of His Majesty's dockyards there were old quay walls of which he believed there were no drawings, and nobody knew what the foundations were really like, so that when they began to dredge to get a greater depth for bigger vessels they found that the foundations were suffering, and they had to keep away from the wall.

They were much indebted to Mr. Buckle for his paper. It was good and practical and told of things that had actually been done. They realised the responsibility of executive engineers in such cases. Mr. Buckle had been fortunate, and they could only envy him and hope that when they were placed in a similar position they should have equally good fortune.

Mr. Burnard Geen asked what was the width of the bridge, which was not stated. He saw that the proportions of the concrete filling of the cylinders were given in a rather unusual way. It was usual to state the proportion of coarse material to cement, the cement being expressed as one unit. The concrete appeared to be very rich for the mere purpose of filling, but there might have been some reason for that.

Another point was that when the girders were being floated out on the pontoon (there seemed to be no counterbracing, even in the central bays), the overhang of 40 ft. at each end appeared to be rather large. He should be interested to know whether any temporary provision was made to counteract the effect of that overhang. One read in the paper of certain deflections, or lateral bendings, he took it, in the tension bars. He wondered whether any temporary arrangement, for example bolting on

timbers, was contemplated or actually adopted, or whether no provision was made for stiffening the tension members when acting as struts. Were they merely left to look after themselves? If they had no lateral support, they must bend and if they were allowed to do so he thought that an objectionable proceeding which, conceivably, might have had bad results.

He did not quite appreciate the connection between the lateral deflection of the girders under the action of a train, and the inference drawn from that as to the quality of the riveting. With regard to the addition of load to the cylinders by chains and tackle the method was good, but the amount of load added, (given as 15 tons in the paper), seemed to be very minute compared with the total amount of weight which must be required for sinking; so that if that load was efficacious the cylinder must have been almost in the position of sinking at the moment when the additional load was applied.

Mr. A. S. E. Ackermann said that the point which had interested him was that which had also caught Mr. Geen's attention, namely, the method of erection shown on page 270, whereby an overhang of about 40 ft. was left at each end of the girders. The end bays of the girders were not so heavy as the others, because they were triangular in side elevation instead of square, hence the overhang was of less importance, and probably the amount of buckling of the tension members was so slight as not to matter. The point interested him because the method of erection was apparently very easy, as Mr. Benedict had remarked. It also was extremely easy from the point of view of the calculation of the stresses in the members. Except for the small overhang, which might or might not be serious—and he fancied that it was not serious—there was no reversal of the stresses. Each section of the bridge was put on a more or less even table, floated out, and dropped on to its supports, and all the members during construction acted as ties or struts as they would do so long as the bridge lasted. He had put on the board a couple of diagrammatic sketches (Figs. 22 and 23),

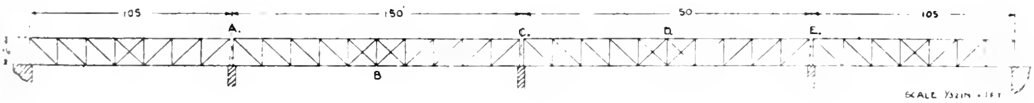


FIG. 22

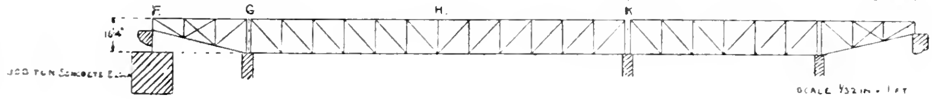


FIG. 23

showing the designs of two railway bridges which had been submitted to him for report, where the erecting stresses were decidedly complicated; in fact if that had not been so the designs would probably not have been submitted to him at all. In the case of the bridge shown in Fig. 22, the end spans were built on the banks of the river and the ends A and E were floated into position by means of pontoons. False joints were made at A and E and the portions A B and E D were built out as cantilevers. A temporary vertical leg or prop was fixed under B and the portion B C was built out as a cantilever. A third false joint was made at C and the portion C D built out as a cantilever and joined to the other cantilever E D. The members would readily see how complicated the calculation of the erection stresses was owing to the method of erecting the bridge; in fact, to use a slang phrase, it played "Old Harry" with the stresses! In the case of the bridge shewn diagrammatically in Fig. 23, the calculations were, perhaps, even more complicated. The end spans and the 90 foot span were built on false-work. The end F was anchored to a 100 ton concrete block, a false joint was made at G, and the portion G H was built out as a cantilever. A second false joint was made at K, the 90 foot span was temporarily loaded with a distributed load (because half the 180 foot span naturally weighed more than the whole of the 90 foot span) and the portion K H was built out as a cantilever and joined at H.

The erecting stresses were allowed to be 50 per cent. greater than the working stresses. He had never heard since of either of the bridges, which were in Africa, so he presumed that they were all right, otherwise, no doubt he would have heard of them!

Mr. A. S. Buckle, in replying to the discussion, said that Mr. Benedict seemed to think the cylinders were very amenable. He could only say that he had always understood that cylinders were not easily amenable, and Mr. Mills and he took particular precautions on that account. They came into their places as they were wanted because they were held by the logs placed around them as described.

Great attempts were made at caulking the cylinders. The cylinder curb was wrought iron with a number of rings, and every rivet had to be caulked, but, for all that, they still seemed to leak, which may have been due to the native labour employed. No doubt they could easily have been made watertight in the shops, and if, when they were made, it had been known that the cylinders were going to be floated out, they would no doubt have been delivered watertight.

With regard to sending men down deep cylinders, he never sent them down more than 10 ft. or so.

Wedges were said to add to the friction very much. In a 10 ft. cylinder the perimeter was something over 30 ft., and the wedge in one place was about 6 inches. He did not think that it added very much to the friction, and whatever was done a certain amount of friction must be utilized to prevent the cylinder from moving out of position.

It was said that the theodolite staging looked as if it would wobble, but it was well braced up on that account, and when standing on it with a theodolite care was taken not to move about too freely.

With regard to the Mannar cylinders, at the beginning of the work the rails had not arrived from home. They had no material for weighting the cylinder, but something had to be done, and 15 tons pressure, produced by the arrangement of chains and tackle, had the desired effect. Without it they would have had to cease work. He read a paper on those bridges in Ceylon at a Ceylon Society, and he must say that the idea was very much appreciated by men who were carrying out similar work.

With regard to tests for skin friction, no tests were made in that way as the foundation was so good.

He was pleased to hear what Mr. Fereday had to say about the construction engineer and the designer coming together. While on that subject, he would like to say something about the marking of cylinders. Each one came out from home carefully marked to go into its position, and bearing a letter and a number, while a line 2 inches wide was painted right down the cylinder to show exactly how it ought to fit. For the marking to be of any use the makers must know the order in which the cylinders were to be used, but here it was discovered that the marking had no meaning. Sometimes the cylinders fitted by their numbers, and sometimes they did not. At any rate, they could not possibly follow the marking, and it had to be abandoned. In some cases the one that they wanted to use next had not even been cast.

He had nothing to say about light girders, but certainly he believed that the weight of the 150 ft. spans had been very much brought down of late years by deepening them. The width of the bridge was 15 ft. from centre to centre of the girders.

It was said that the concrete filling was rather rich. At the bottom they did not use concrete at all. There was a wad of cement first and then they filled in with sand, which he thought was about 20 ft. deep. That was a very usual practice in India.

As regarded the girder overhanging and the reversal of stress due to this, they put a strong timber strut between the tension bars (which were clearly seen in Fig. 20.), so as to take the compression. What would happen was realised, because even

in erecting the girders on the stagings the tension members buckled slightly, but it was nothing serious.

Some remarks had been made upon the cost of the bridge and Mr. Fereday suggested that it was out of all proportion to the cost of the girders.

Some of the chief items that went to make up the cost were :—

	£
Cost of girders	15,910
Cost of cylinders	15,910
Freight on above two items	883
Erecting and painting girders	8,904
Labour and materials in timber, pile driving, sleepers, &c.	6,706
Adjustable charges to be credited	862
	£49,175
Balance due to sinking cylinders, concrete, establishment charges and various other items	16,825
Total....	£66,000

It was evidently unfair to make comparisons of the total cost with the cost of the girders, for the cylinders alone cost as much as the girders.

The high cost of girder erecting was largely due to specially expensive labour having been brought from Rangoon in order to finish work before the floods rose. This was an act of policy that had been deliberately undertaken for higher financial reasons.

From Sir Francis Spring's great work on *The Training of Indian Rivers* it appeared that the actual cost of such bridges was about 500 rupees per foot, so that in the circumstances 560 rupees per foot did not seem very high, and but for the special circumstances mentioned the cost would have been well under this rate.

Mr. Benedict had made some rather disparaging remarks on Indian labour, but he (the Author) had always been most fortunate in some of the men that he had employed and considered the men known as Bombay Khallassies to be often wonderfully skilled in the practical work of structural engineering, being, as they were, all born sailors.

So much had this been the case that in the two works in Burma and Ceylon, mentioned in the paper, the head men had been in both cases the same individuals, and the association of the author with some of them dated from a still earlier period, and in quite another part of the East. In his opinion success with Indian men was largely secured by knowing how not to put round pegs into square holes.

2nd November, 1914.

H. C. H. Shenton, President, in the Chair.

USES OF THE HYDRAULIC MINING CARTRIDGE.

By James Tonge, M.I.M.E., F.G.S.

The difficulty of removing rock and other material, in places where the shock attendant upon blasting operations would be damaging and dangerous to surrounding strata or foundations, is one which has not hitherto been thoroughly overcome.

The enormous initial power generated by the sudden decomposition of explosive substances has enabled great quantities of natural or artificial beds to be displaced, and a great portion of the work of the Civil and Mechanical Engineer is involved either directly or indirectly in operations of this kind. The objection to the use of explosives however, in many circumstances, is that the effect of blasting can seldom be harnessed or controlled so as to prevent the disintegration of the material beyond the area which it is desired to dislodge. In the case of many metalliferous mines, and sometimes of quarries, this is not a great drawback as it may not only be unnecessary to limit the operation of the " shot," but it may be actually desired to have the material in a pulverised condition. Even in this case, however, it should be remembered that this is not an economical means of obtaining such a result, for pulverisation by explosives involves enormous waste of power as it usually represents great excess of explosive charge ; in other words, the use of explosives must involve either the risk of accident through an insufficient charge, or the production of misapplied energy.

It is for the purpose of avoiding these drawbacks and in order especially to take greater advantage of natural lines of cleavage or of bedding in the material to be dislodged that efforts have from time to time been made to provide what may be termed more rational or scientific means in the shape of mechanical substitutes for blasting. Machinery of one kind or another is used for almost every other operation in connection with rock excavation and the breaking up of earthworks ; it is only necessary to refer to mechanical diggers and dredges, drills for boring holes, groove cutters, tunnelling machines, shaft sinking machines, and mechanical coal cutters.

The simplest form of mechanical means for breaking ground is, of course, the wedge, and this is used in varying lengths and shapes, in metalliferous and in coal mining, in all parts of

the world. Various improvements on the simple wedge have been used at various times, viz., the stub and feather and the multiple wedge. The former consists of a steel "stub" or wedge driven in between two tapered liners of steel called "feathers" which have their thin end near the front of the hole. The multiple wedge is placed in a hole previously drilled and has liners also, but a pair of "feathers" may be inserted between them, driven up as far as possible, and then a second or a third "feather" may be used until the rock or coal is broken down. In coal mines special efforts have been made to devise mechanical wedges capable of breaking down coal, notably those invented by Bidder, Burnett, Shreeve and Hall, and these have been used to a greater or less extent in a few mines. In some of these the wedge was driven in by means of screw and handle, like a hand drilling machine, and in one case by hydraulic power.

These machines are not now in use and it may be taken that they have proved to be impracticable. This is no doubt due to the great pressure put upon them, even under favourable conditions, and the difficulty of devising and supplying a hydraulic pump capable of working at high pressure for a considerable time. It must also be remembered that a mechanical wedge must perform more work than that required to wrest the rock or coal from its position, as a certain amount of power is consumed in overcoming the friction of the sides of the wedge as it is driven up. Again, it is a disadvantage to have the material at the front of the hole breaking away as the wedge enters—the full weight of the falling material should if possible be utilised to assist the operation. With this object in view machines have been designed to operate at the back of the hole first, the wedge being drawn towards and not driven from the front. Except in the case of the simpler forms it may be said that no mechanical wedges are now being used with success for excavating purposes of any kind.

The Hydraulic Mining Cartridge.—The hydraulic mining cartridge differs from all other mechanical substitutes for blasting. It is not worked on the principle of the wedge, and consequently the power expended in forcing a wedge into the hole is saved. Instead of employing a wedge, the disrupting effect is obtained by means of a number of small rams or presses working at right angles from a strong cylinder of steel. (Fig. 1.) In order to make these rams more effective in their operation, by obtaining a greater travel from their original position, they are made of a duplex or telescopic form, one part sliding and fitting upon the other (Fig. 2.) In some cartridges these pistons operate from each side of the cylinder alternately, thus greatly increasing the travel. To retain the rams in position, a sliding plate is used fitting in grooves in the barrel (*b* Fig. 1);

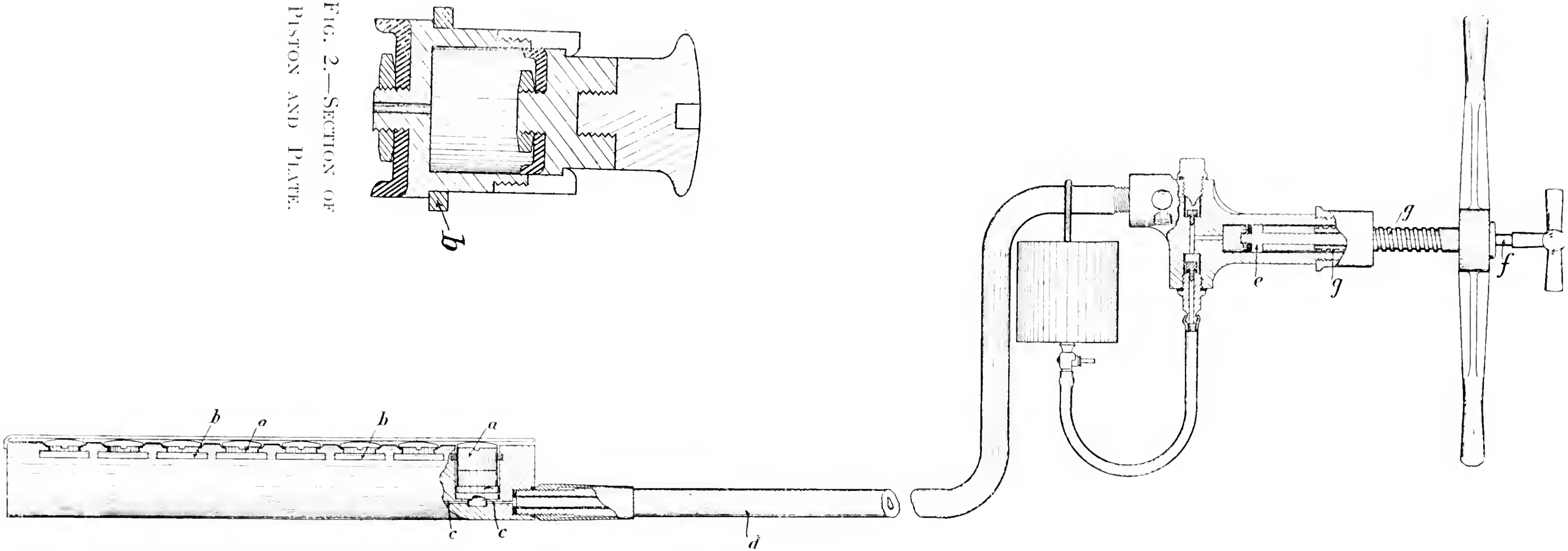


FIG. 2.—SECTION OF PISTON AND PLATE.

FIG. 1.—SECTIONAL ELEVATION OF THE HYDRAULIC MINING CARTRIDGE.

this is so formed and secured that it is perfectly rigid and firm when the machine is in operation, but is readily removable if it is desired to detach or replace any of the rams. By a suitable arrangement of passages (*c* Fig. 1) a communication is made between each of the rams, whereby simultaneous action is obtained. Machines are made of various diameters, viz., $2\frac{1}{2}$ in., $3\frac{1}{4}$ in., and 4 in., and of various lengths, say with 8, 6 or 5 rams, the smaller diameters having the larger number of rams. Pressures of 3, 4, or 5 tons per sq. in. are usual, so that machines are made to withstand great stresses.

The Pump.—The cartridge is operated by means of a pump (Fig. 1) to which it is directly connected by a pipe (*d*). The pump is of special design. At the commencement of the supply of water, it is desirable that the latter should be supplied in such quantities as to fill up quickly all the spaces within the rams and passages, while at the same time allowing the operator, when the rams begin to move and the pressure to increase, to supply a less quantity of water, but at a greater pressure, to complete the final operations of the rams. This is done by having the piston (*e*) operated by the piston rod (*f*) which passes through a supplementary or hollow rod (*g*) and has an appropriate handle for operating the piston within the pump cylinder. By these means the piston may be quickly reciprocated by the user moving the small handle until the desired quantity of water has been supplied or until the pressure to be exerted over the rod (*f*) is beyond the power of the user, when the supplementary rod (*g*) may be brought into use to finish the operation, this advancing by screw motion, and great pressure being obtainable in this way.

Method of Working.—After the rock or coal has been prepared with one or more loose sides and the drill hole of 3 in., $3\frac{1}{2}$ in., or $4\frac{1}{2}$ in., has been drilled to a suitable depth (say three or more feet), the cartridge is pushed in with liners if necessary. The water tank is filled and hung on the pipe, the rubber suction pipe coupled, and the taps turned. The small handle and then the large one are operated as already described. The pressure being fully on, the enormous power of the apparatus is soon apparent, for the rock or coal is heard to be rumbling and cracking. This is allowed to continue until the breaks are of such a size that the mass can be pushed or pulled over and usually is in such condition as to be easily and safely handled.

Line of least resistance.—It is easy to understand that when a shot is fired in rock or concrete, the direction of the breakage will be chiefly in the line of the weakest part. If the material is of uniform strength this direction would be a straight line from the explosive to the nearest unsupported edge. But

stratified beds, seams of coal, and walls of stone or brick, are not usually of uniform strength; rock and coal beds contain breaks, cleats, and faces, while concrete beds are invariably irregular in constitution or structure. It follows, therefore, that the line of least resistance is not necessarily the shortest line from the charge to the surface. The difficulty and danger of explosive firing is that whatever this line may be, it is not often possible to make use of it; the pressure generated, though not equally effective, is equally applied in all directions owing to the instantaneous character of the decomposition. This involves high temperature in the explosive gases, a large portion of the heat being absorbed and wasted in the portions which are not capable of being blown down. When mechanical means are employed the time involved in the operation allows the whole of the power to be exerted and applied in the desired direction without waste of heat energy. Not only is power lost in heat energy in the case of explosive compounds, but the result often proves that there has been counter action whereby the rock displacement is reduced through one line of force operating against another, closing in or reducing the area of broken ground.

In practice it is found possible so to arrange the hydraulic cartridge holes as to enable much greater areas of material to be moved than could be done with a safe quantity of explosive, while in some cases the displacement has been greatly extended by the use of small-sized bore holes towards which the slowly-developing line of least resistance can assert itself. In other words the power exerted by the rams can be controlled, after a little experience, so that the full pressure can be usefully applied.

Use in Mines.—The appliance was originally introduced into mines in order to supply the acknowledged need of a different method for bringing down coal in mines in the best possible condition after it had been undercut by hand or machine. The use of high explosives for this purpose, apart from the element of danger, has always been considered undesirable by mining experts, because in using them coal is shattered and wasted and dust made. Now that coal has to be won from greater depths than formerly, and the distances and areas underground increase, the dangers and extent of explosion have proportionately increased, as many recent colliery disasters have shown. The mines in which the cartridge has been chiefly adopted may be divided into two classes:—

(*a*) Where the coal is so friable as to render the use of explosives impossible for commercial reasons.

(*b*) Where the condition of the mines in regard to gas, etc., render shot firing an exceedingly dangerous proceeding.

Of course the question of cost enters very largely into the matter. As is usually the case when a new appliance is introduced, its qualities are quickly estimated from the effects upon the working expenses. At a later stage it will be seen that its effect upon the working cost is slight, whilst its general advantageous effect upon the selling price of the coal is quite striking. During the past ten years the appliance has been employed in mines in Great Britain, the United States, Russia, Japan, Germany and Austria.

In removing coal a series of holes is drilled in the top of the seam, adjoining and running parallel with the roof. These holes are at intervals determined by working conditions, usually from 6 ft. to 10 ft. apart and from 3 ft. to 5 ft. deep. The operator begins at the first hole and pumps off each in succession, usually leaving the supporting sprags to be removed by the collier, who fills the coal thus broken and prepares the coal behind for a repetition of this process. One operator can pump from 30 to 40 shots per working shift of eight hours, using only one machine, which lasts with repairs from three to four years. This procedure is adopted where a large wall of coal has been opened out, and where the coal is got in pillars and headings the process is somewhat modified. The coal across the face of the heading is undercut (almost universally now by a percussive machine operating from a fixed standard) and a vertical slot or "shearing" is cut up the centre of the coal, thus providing

FIG. 3.—HYDRAULIC CARTRIDGE IN USE IN COAL.

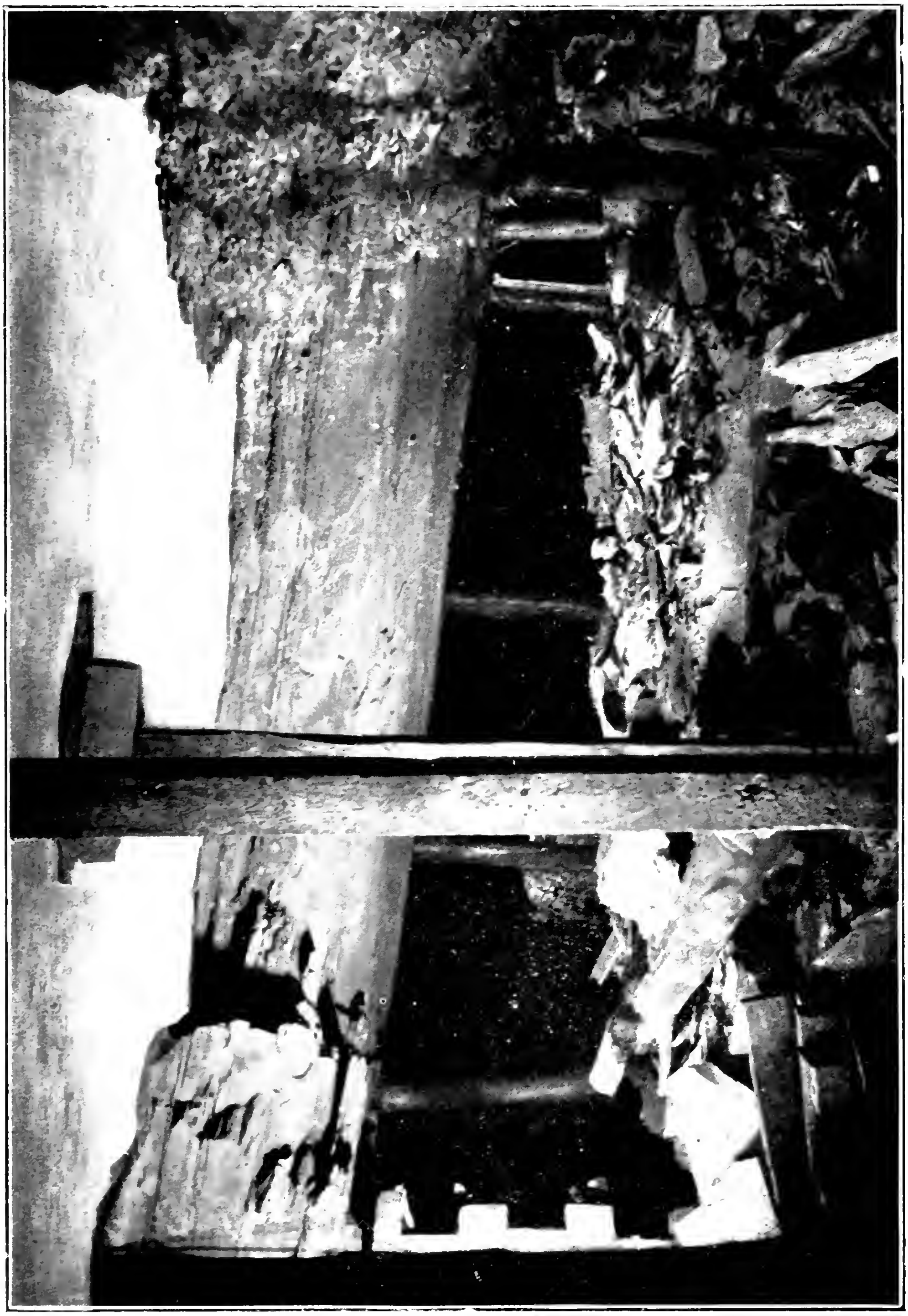


FIG. 4.—EFFECT OF HYDRAULIC CARTRIDGE IN ROCK IN MINES.

a loose end. One hole on each side of the "shear" is then sufficient to bring down the coal. The holes are placed as near as practicable to the fast side in order to bring the coal down as near the "fast-corner" as possible. (Figs. 3 and 4 shew the cartridge in use in mines).

Among the mines in which these machines are at present in use are the following :—

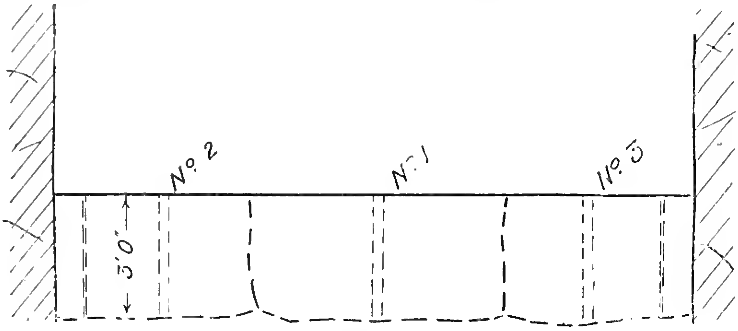
Colliery No. 1.—At this colliery an average of over 1,000 explosive shots per week were formerly fired in coal in the various mines. By the introduction of the hydraulic cartridge the whole of the explosive shots have been discarded and there is not now a single shot in coal in any seam. In one seam alone a total of 28,500 hydraulic cartridge thrusts were made in one year, by which it is estimated that 92,626 tons of coal were produced, or about $3\frac{1}{4}$ tons per thrust. The seam was 3 ft. thick and four cartridges were in daily use.

Colliery No. 2.—In a seam using five hydraulic cartridges 450 tons of coal are produced per day, of which 75 per cent. is large coal and 25 per cent. small. When the coal in this seam was brought down by explosives the percentage of large coal was 65 per cent. and the percentage of small was 35 per cent. The average price of large coal was 13s., and of small coal 7s. per ton. The profit obtained by the use of the cartridges on this seam on 450 tons is therefore, £14 5s. per day. Fifteen machines are employed at this colliery making a total advantage over explosives of £42 15s. per day. Moreover, an extra 6d. per ton is obtained for the coal brought down with hydraulic cartridges, on account of its greater hardness and freedom from dust.

Use in Reservoirs, Docks, Harbours and Canals.—The operations in these places have all certain features in common which allow of their being classed together, and they may be divided into three classes.

(*a*) *In open Trenches.*—The difficulty of removing rock from confined spaces where it is necessary that no shock or vibration should be transmitted to surrounding strata is a very vital one. The introduction of the hydraulic cartridge into this class of work will, it is hoped, help to solve this question. During the past few years it has been thoroughly tested under most varied conditions and in all classes of deposits.

The work in trenches usually proceeds as follows :—A number of holes are drilled (Fig. 5.) say 2 ft. 3 in. back from the edge of the rock, about 5 ft. apart and 3 ft. 0 in. to 5 ft. 0 in. deep, according to circumstances. The holes are, when possible, bored by a power drill operating from a tripod. By these means suitable holes, of diameters up to about 5 in., can be quickly drilled. The centre hole is pumped first and provides a loose end



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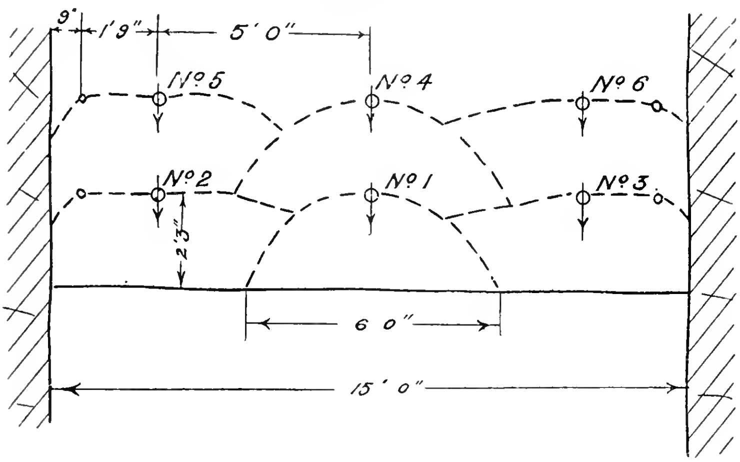
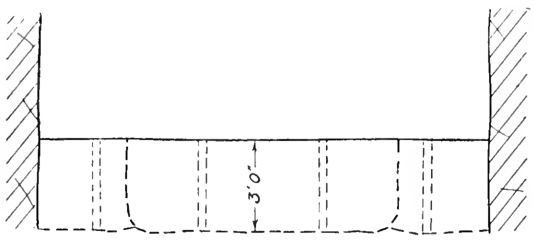
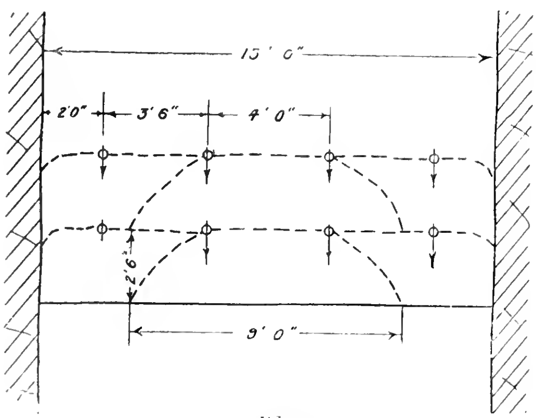


Plan.

FIG. 5.—TRENCH EXCAVATION.



Elevation.



Plan.

FIG. 6.—TRENCH EXCAVATION.

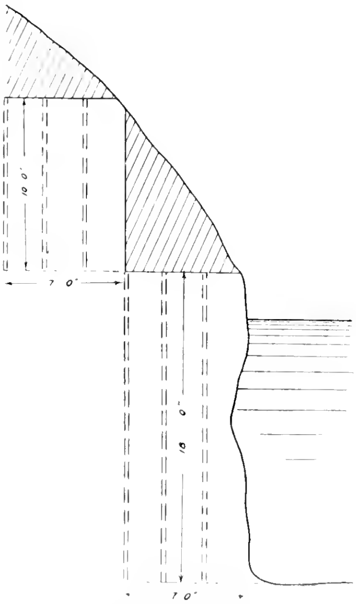
for those on each side. These are pumped in turn until the fast side is reached, where it may be found advisable to drill a small 1 in. diameter hole, say 9 in. from the fast side, to enable the cartridge to break the rock as close to the fast side as possible. Sometimes this method is varied by pumping off two centre holes simultaneously and placing the last holes 2 ft. 0 in. from the fast side, leaving out the small diameter holes. (Fig. 6.) In this case the holes could be 2 ft. 6 in. from the front edge and two machines would be required.

Taking a trench 15 ft. in width and holes 3 ft. in depth, the first method would necessitate three cartridges and two 1 in. holes to get 100 cub. ft. of rock, while the second method would require only four cartridge holes to remove 112 cub. ft. During the operation of the machine it is possible to see the rock slowly fracturing at each turn of the handle. Work of this character has been done by the cartridge in connection with the Derwent Valley Water Works, and the Cwm Taff Reservoir, Liverpool Corporation, and tests are now being made for the Abertillery Water Scheme.

(*b*) *Under Water.*—The appliance has been used in many cases under water, chiefly to remove rock, either from the sides of canals, or from the sides of harbours and docks, where it was obviously impossible to use explosives, the machine being operated from the bank or from pontoons. A typical case will serve to illustrate the suitability of the cartridge for this class of work. The rock to be removed was partly projecting from the side of the canal and it was necessary not only to remove the mass in the water, but also that upon the bank, as shown in Fig. 7.

The rock was New Red Sandstone and the depth to the bottom of the canal 18 ft. 0 in. It was decided to remove the mass the full depth at one operation. A series of holes was accordingly drilled 6 ft. 0 in. apart, 2 ft. 4 in. back from the edge, and 18 ft. 0 in. deep. These were pumped off in succession and the operation of the cartridge at this depth sufficed to break the rock right up to the bank in nearly every case. In one or two holes it was found necessary after operating in the bottom half to draw the machine up about 9 ft. 0 in. and operate again. During the operation divers were below water ascertaining the position and extent of the breaks and directing the operator above as to how to continue the thrusts. The portion shaded (Fig. 7) was removed by hand and another series of holes was put down 10 ft. 0 in. deep, 6 ft. 0 in. apart, and 2 ft. 4 in. from the edge, to break up that portion of the rock to be removed.

In the Alexandra Docks at Newport, and in the new dock at Swansea, the appliance has been used to break up ledges of rock occurring in the vicinity of walls which would have been



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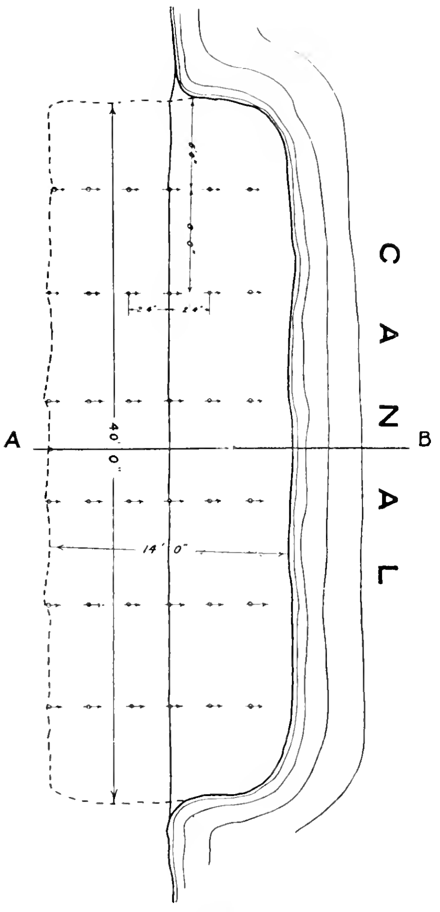


Plan.

FIG. 7.—EXCAVATION OF ROCK ON CANAL SIDE.

damaged by the use of explosives. The holes were put in and the cartridges inserted under water by divers and pressure was applied from the pump placed on a raft on the water.

(*c*) *Dock or Harbour Walls.*—Hydraulic machines have been used for some years at the Dover Harbour Works for the purpose of detaching the large concrete blocks used in the harbour walls. These blocks are of great size and weight. By inserting the drill hole along the bottom of the block and placing the cartridge about half-way under it, the whole mass is slightly lifted and tilted without breaking, and being thus released from its bed is easily lifted on to a wagon by a crane. Machines are being used for a similar purpose in other docks.

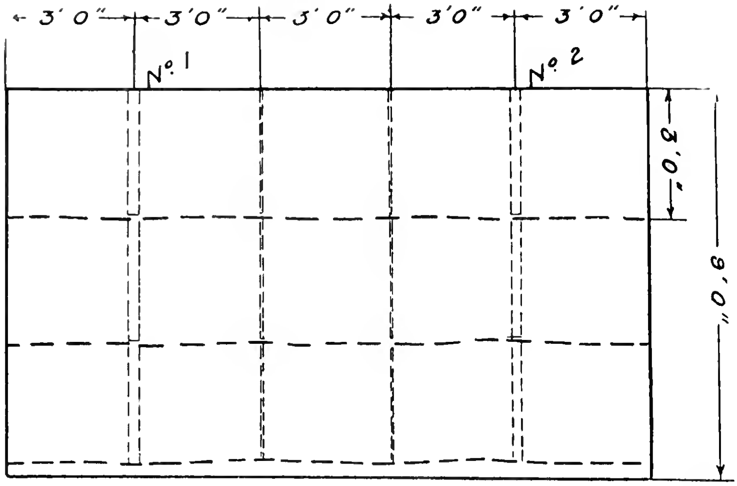
Excavation of Foundations.—The question of the removal of concrete foundation beds by a method which would not involve explosive blasts and would avoid the slightest damage to machinery or buildings has been carefully studied recently by the writer, and had never been thoroughly solved until extended trials in all parts of the British Isles had been made.

The effect of powerful hydraulic pressure upon concrete is interesting. In the case of sandstone and shales there is comparatively slight crushing of the rock before the full pressure of the rams has the effect of causing the mass to bend; considerable pumping and consequent travel of the rams is then necessary before the rock finally begins to crack and break away; with concrete, however, there is usually a perceptible interval during which the rams are crushing or compressing the material and no movement is noticeable; after this is accomplished a few more thrusts of the rams cause the whole mass to break up without any indications of bending. It may still be necessary to continue to apply pressure and to increase the size of the breaks in the mass, but the greatest shattering effect will have been accomplished at the first disclosure of the cracks, the pressure required to break the mass afterwards gradually diminishing.

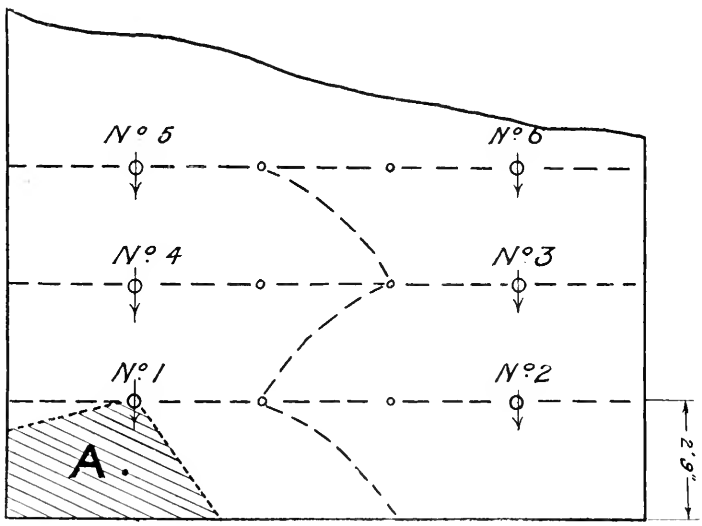
In such material, explosives invariably have the effect of "hacking a way through" by the shortest direction to the unsupported edge (Fig. 8), pulverising the mass but failing to take advantage of pressure gently applied, by means of breaks which spread and widen, and to utilize the weight of the concrete itself to increase the scope of the operation. Numerous experiments in this class of work shew that 60 to 70 cub. ft. of concrete can be easily removed per thrust.

The general procedure in attacking beds of concrete may be divided thus:—

1. By vertical cartridge holes.
2. By horizontal cartridge holes.



End View.

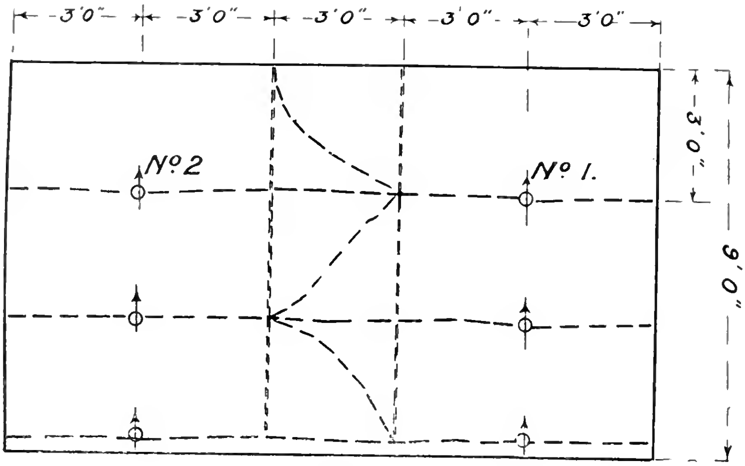


Plan.

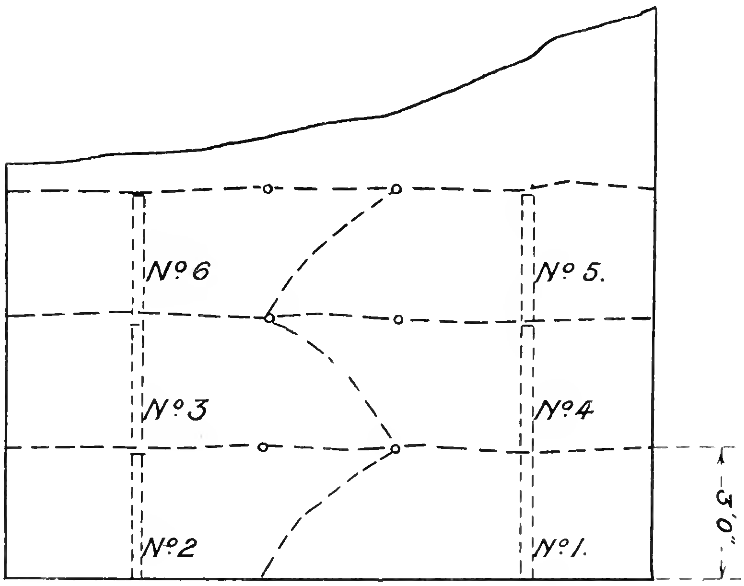
FIG. 8.—CONCRETE BED EXCAVATION.

1. *By Vertical Cartridge Holes.* (Fig. 8).—This method is most applicable to places where power can be easily obtained to bore the holes by tripod and power drills. The cartridge holes are drilled about 3 ft. deep and 2 ft. 9 in. back from the front edge of the bed. It has been found of great advantage to drill small diameter holes three feet away and in line, to which the fracture will break. In this way a bed 15 ft. 0 in. wide could be broken all across by two cartridges and two small diameter holes, amounting to 124 cub. ft. of material.

2. *By Horizontal Cartridge Holes.* (Fig. 9.).—In this case the holes would be 3 ft. 0 in. deep and made to lift 3 ft. 0 in. of



End View.



Plan.

FIG. 9.—CONCRETE BED EXCAVATION.

material per thrust, the vertical small diameter holes being put in as before. The amount of material moved per thrust is 67 cub. ft. The effect of lifting up is to break a larger quantity of material and in much larger pieces than is the case with vertical holes. With the latter the concrete is found to be very well broken up, and ready for handling without the further use of tools. Horizontal holes on the other hand, are more suitable for beds where foundation bolts are embedded in the concrete.

There appears to be no class of work so suitable for this machine as the removal of concrete beds. The following recent case is a typical example. At a Municipal Electricity Works

the cartridge was used to remove the main engine room foundation bed. Within a radius of 40 yards from the scene of operations, many of them within the same building, were very valuable Lancashire and water tube boilers, electrical and steam engines and the main switch board and cables. Needless to say the work had to be carried out with as little vibration or shock as possible. Explosives were out of the question, and the ordinary method of hammer and wedge would have proved an extremely long, tedious, and expensive process. The bed consisted of a solid mass 14 ft. 6 in. wide, 26 ft. 0 in. long, and 10 ft. deep, composed of hard cement concrete for the most part, and reinforced with numerous foundation bolts.

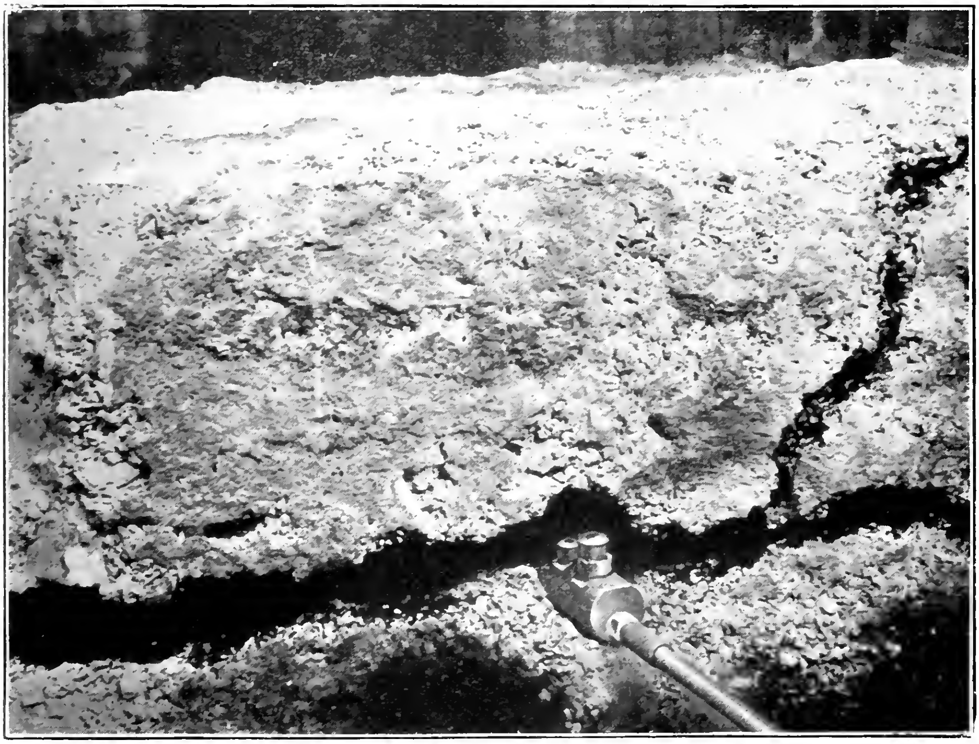


FIG. 10.—HYDRAULIC CARTRIDGE IN CONCRETE BED.

It was considered unnecessary to instal power drills on the work and the holes in consequence were drilled by hand. The majority of these were horizontal and were put in by means of an ordinary twist drill and ratchet machine by two men. These men could drill fairly easily 3 ft. 0 in. per hour. One hydraulic cartridge only was employed. The general procedure was to keep the drillers at work putting in holes all round the side of the concrete, the machine following when two or more holes were ready. The holes were on an average 6 ft. 6 in. apart and from

2 ft. 6 in. to 3 ft. 0 in. below the surface in the case of horizontal holes. The vertical holes were drilled only in special places to trim down the vertical edge, and in these cases the measurements were about the same. The employment of shot holes to form a breaking point was considered unnecessary. (Fig. 10 is a photograph of one of the horizontal shots).

The debris thus broken was removed by a gang of six men who were kept busily employed with pick and shovel, and wedges were necessary only to break up the larger pieces to a suitable size for handling. It was found that the amount of material broken up in the course of three or four shots was quite sufficient, in consequence of the limited and cramped working area, to keep the men busily employed for the rest of the day. Had it been possible to place more men on the bed, there is no reason why a much better output should not have been attained, but in this case it would have been necessary to break open the wall in several places, which was not considered advisable. The whole bed weighing approximately 200 tons of concrete was removed in twenty working days. About sixty shots were necessary to complete the work, making an average of nearly 3½ tons per thrust.

The cost of the work was as follows :—

Labour per day, including operator, drillers, navvies, and foreman... ...	£2	15	0	
Amount of material removed—average 10 tons per day		4	9	per ton.

The above cases will be sufficient to show that with a mechanical substitute for blasting capable of exerting a total pressure of 150 or 200 tons upon rock, coal, concrete, masonry, etc., and in such manner as to cause no shock to the material in which it is operated, there should be possibilities of usefulness to engineers, not previously contemplated.

Discussion.

The **President** said that, in proposing a vote of thanks to the author for his excellent paper, he had to inform those present that they had the honour that evening of receiving some of their Belgian brother-engineers. The Society had a great respect and admiration for the heroic Belgian nation, and was glad to be able to show its sympathy by receiving the Belgian engineers and welcoming them to its meetings and to its offices while they were staying in England.

With regard to the paper, the subject of it was one of great interest, not only to mining engineers, but to water engineers and sanitary engineers. In fact, there were very few branches of engineering in which one might not at times have to remove

great masses of rock or concrete. The method dealt with was particularly useful in sewerage work, where tunnels had frequently to be driven through streets with houses on either side of the road. Personally, he was very nearly using it recently at a well close by a building where he had to remove rock from a heading, and where it was not possible to blast, owing to the danger of shaking the walls. Unfortunately, he was then dealing with a very conservative contractor, who managed to get his rock out by another process. He hoped to have a chance upon some future occasion of using the method described by the author.

The vote of thanks was carried by acclamation.

Mr. J. D. Haworth said that Mr. Tonge, who was a well-known mining engineer, had been almost a lifelong friend of his, they both being Lancashire men. He thought that his friend was of a somewhat modest disposition, as for one thing he had not mentioned in the paper that the invention of the hydraulic mining cartridge was his own, and also that a few years ago, when the uses of it had been demonstrated in coal mines, the Society of Arts awarded him the Shaw Prize and Gold Medal for the best invention during the year for the means of saving life therein. If the author had not many friends present at that meeting, at least he must have a considerable number amongst the colliers, who had appreciated the safe use of the cartridge when getting coal.

The paper described very clearly the many useful purposes to which the cartridge had been put, and the advantages secured, He had tried the cartridge in two or three instances, one of which had been described by the author. This was the case of the Municipal Electricity Works at Bedford, where a large mass of concrete had to be removed in a very difficult situation. The result was most successful, the whole mass being removed without the slightest damage being occasioned to any of the surrounding machinery, the greater part of which was kept running whilst the work of removal was in progress.

He had also tried the cartridge for getting rock in open trenches and in tunnel for sewerage works, and the author had shown on the screen one or two illustrations of it. In regard to the tunnel, where the cartridge might have proved of great service in excavating the rock instead of the usual method by explosives, there was only 11ft. of cover on the top, the street under which it was being driven was a narrow one, two other sewers, as well as gas, water and electricity mains were almost adjacent, so that great risk attended the operations. Unfortunately, the tunnel was too far advanced when the cartridge was brought for trial to allow of any alteration being made in the contractor's arrangements for getting out the rock.

The cost incurred by the use of the cartridge was an important point, and, although in the case of the concrete bed just mentioned it worked out to 4s. 9d. per ton, it was, he thought, a case where the surrounding conditions should be taken into account, and perhaps, most important of all, the fact that there was entire freedom from danger to the adjoining machinery.

There was also another point, namely, the difficulty of quickly drilling the hole in the rock or concrete for the insertion of the cartridge. Frequently the work of removal of rock or concrete masses had to be carried out expeditiously, and one of the author's difficulties had been that of getting this hole drilled as quickly as possible so that very little delay was caused to the workmen engaged. He (the speaker) had recently seen a machine at work which he felt sure was capable of drilling a 4½ or 3½in. diameter hole in hard rock in far less time than by manual labour. If such a type of power drill as he had mentioned were used there might be cases where the use of the cartridge would become more general, as the cost of drilling would be considerably reduced.

In the illustrations shown by the author of the use of the cartridge for getting coal, it seemed to him (the speaker) that the lumps broken were too large to handle easily and be removed by the workmen, and he was of opinion that rock of any kind, especially in tunnel work, should be broken into as small pieces as possible. To do this he thought that a good method would be to drill the holes for the cartridge at more frequent intervals as well as some others of smaller size. The latter would create a free outlet for the pressure from the cartridge thrust, and ensure the rock being split up into smaller pieces.

Mr. G. B. Latham said that he understood that the cartridge was a substitute for the use of the " wedge and feather " in cases where manual labour had to be used in order to prevent shattering surrounding structures. As far as that was concerned he should like to see it applied. It was probably a much cheaper method than the old-fashioned method which he had had reason to apply only once in his career, namely, at Newport (Mon.). The cost of getting the rock, i.e., Old Red Sandstone, was about 15s. a cube yard, or 9s. a ton, the author's experience showing a saving on this of 4s. 3d. a ton.

With reference to explosives, they could always be made to be used as required. He did not know much about getting coal, nor did he know much about getting anything except what concerned his own profession, but he had noticed the getting of salt in the Northwich district. There the salt was got, not with high explosives, but with the old-fashioned black powder and with the old fuse. When the holes were drilled, the man lit his charges and everybody stood back a short distance only. It

was a rock which would easily shatter, and which required no explosive force. He thought that the author's invention would be very useful in that direction, as probably the means adopted at present were not economical. The charge used in blasting could always be varied according to the nature of the rock which had to be moved.

Mr. Pierre de Thier (de l'Association des Ingénieurs sortis de l'Ecole de Liége) warmly expressed his thanks to their English brother-engineers for their sympathy. Members of the great family of engineers, they had been received as proven brothers, and they wished to show their thanks and gratitude, not only to the members of the Society, but also to the great English nation.

Their unforeseen sojourn in England would serve only to increase the cordial relations already existing between the two nations, and they were convinced that they would profit greatly by it in seeing for themselves the marvels that the industrial and commercial genius of England placed before their eyes.

The paper they had listened to had the greatest interest for them. The use of the hydraulic cartridge was of great value in mining and in certain special works, especially as Mr. Tonge had pointed out, in very thick beds of coal, where, as in England, it is sought principally to increase the proportion of large and diminish that of small coal, in view of the great difference of price between the two kinds of coal. The same advantage was found in other countries, such as France, America, Japan and Russia, but it was less noticeable in a country like Belgium, where the conditions of the strata and prices are different. One advantage of this process made itself more felt in certain cases where the immediate proximity of water, gas or compressed air mains, reservoirs, machine foundations, etc., forbade the use of explosives, the bursting of which would produce shocks and fissures in the earth that would be fatal to such installations.

He would especially draw attention to the usefulness of this process in marble, slate and lithographic stone quarries, where the value of the product increased greatly with the area of the stones that were obtained. He would mention the case of a quarry of rare marble that had been worked by the Romans, and which, reopened in modern times, was worked by means of dynamite, resulting in the ruin of the quarry and of its exploiter. This failure could have been avoided by the use of the hydraulic cartridge.

In conclusion, he again thanked the Society for the welcome given to their Belgian comrades, and the English nation for the large, generous and delicate hospitality that they had extended to all Belgians.

Mr. Henry C. Jenkins said that the use of such an appliance as the author had described was manifestly advantageous for recovering better values from coal seams and in avoiding damage and offering general convenience in special cases; but the appliance also marked a certain departure from an old established mining practice, as viewed from the "metalliferous" rather than the "non-metalliferous" side. Everyone was aware of the big toll that had been taken in the lives of miners, and particularly metalliferous miners, owing to the dust from percussive machines, machines that had come into use for drilling the holes of small diameter needed for the very high pressures resulting from explosives. The author's machine presented new problems in non-metalliferous mining because it used holes of very much larger diameter than had previously been needed. Such a use had an interest at the present moment because it seemed to be a possible way in which in the future some of those lives which were now being lost from fibroid phthisis amongst the workers with percussive machines might be saved. If the holes could be drilled in hard ground by rotary machines and the ground worked equally as well as by means of hydraulic cartridges then a great many lives would be saved. One of the things which engineers had to bear in mind in their practice was that they must prevent any loss of life or limb wherever they possibly could. Unfortunately, up to now this work had demanded a certain toll in health and life, however much engineers had sought to avoid it. At the present time, despite many precautions, each of which seemingly should prevent it, fibroid phthisis so followed the use of percussive machines that in many districts the life of a man working a rock drill was measured by a few years only. Another mining danger was from falls of roofs. The use of explosives, no doubt, was responsible for many of those falls, which otherwise would be avoided. The sudden shock of the explosive was transmitted to places where it was not wanted, and damage was done where it was not desired. He would rather not go outside the strict letter of the paper, but it seemed to him that the paper did involve the question as to how far rotary machines could now be substituted for drilling holes economically in hard ground in the place of percussive machines.

He would like to ask the author how far he had been successful in driving headings in hard ground, and what was the size of the smallest heading which he had managed to drive. In the ordinary way, in driving a heading in hard ground the practice was to put holes in the middle of the heading first to shatter the centre of the heading (this might always have to be done by explosives), and then to break down the sides afterwards. Perhaps the author had work in his experience which would guide engineers as to how far they could use his pressure machines for the latter

part of this work. As to rotary drilling machines, the introduction of which was so desirable, engineers were getting better material (other than diamond) at the present time for the cutting tool than they used to have. Some of the more recently introduced steels were nearly hard enough to attack quartzose rocks.

The shattering effect of explosives was very often required in metalliferous mining work ; but it would be a pity if such appliances as the hydraulic mining cartridge could not be further used in certain cases.

Mr. Charles Moss, a contractor, said that he had seen the cartridge in use. One of the sewers in connection with the Bedford Main Sewerage Works was in a main road about 40ft. wide, which was greatly used, and bordered by houses, some of which were very old and of light construction. The difficulty was to obviate the risk of explosives in the main street, and to avoid damage to life, property and adjacent sewers, a portion of which latter crossed the new sewer in several places. Therefore, those in charge of the work decided to drive a tunnel. Had he seen the cartridge of the author he would have adopted the open cut method as being very much cheaper. Unfortunately, the cartridge was not brought to his notice until the length of sewer was practically completed. From what he had seen of it, if he had the same length of sewer to do again, he should certainly use it.

One great thing was to have an efficient drill. He believed that when the author first brought his cartridges down to Bedford the holes were all hand-driven holes, and he thought that that fact accounted for the cost. Since that time he had seen one of the author's drills at work with compressed air It acted very expeditiously, and he (the speaker) thought that it was quite an economical proposition now to use a cartridge in open cut when the conditions forbade the use of explosives or rendered their use dangerous.

Mr. R. W. A. Brewer remarked on the limitation of lifting effort, given in the last paragraph of the paper as 150 to 200 tons, and inquired whether this referred solely to the apparatus which had been constructed by the author's firm or if it were limited in some other way. He also suggested that limitation might be due to some tendency of the main body of the apparatus to distortion due to irregularities in the surface of the containing hole, and would be glad of information as to whether distortion of a permanent nature had occurred in practice. Mr. Brewer suggested that it might be advantageous to vary the pressure exerted by the individual units throughout the length of the apparatus, as in the ordinary way fracture occurred from the free face of the rock inwards, and the bursting effort would be

proportional to the distances of the various pressure points from the inner end of the fracture.

Reply.

Mr. James Tonge, replying to the discussion, said that one speaker had referred to the use of black powder for blasting salt rock. That was really in line with the use of the hydraulic machine, which operated slowly and gradually. The old-fashioned explosives had the very distinct advantage that, owing to the length of time required before the gases attained their full temperature and pressure, it was possible to get the power exerted in a more effective way. He thought that if it were not for the element of danger associated with black powder, all users of explosives would agree that the old-fashioned slow-working explosives had always been most satisfactory. It was only carrying the principle a little further to apply it in the form of hydraulic power.

With regard to Mr. Jenkins' point, rotary drills had been used for making holes on many occasions, and it had been found that the diamond drill was quite satisfactory when used as a hand machine. It was very necessary to have a regular and smooth hole, and the diamond drill gave such a hole much better than any percussive drill could possibly do. It appeared to him that it would also have the effect of greatly reducing the amount of dust that would be made in the drilling of the hole, and not only would there be a smaller quantity of dust made, but that dust would be of coarser texture.

As to the driving of headings, he must say that in ordinary tunnelling he had not been entirely successful, chiefly because of the difficulty of obtaining a suitable drill for putting holes in easily and quickly. It was not possible to blast from the solid. If the rock was to be broken with a loose end at all, it was necessary to be able to put in small holes readily and easily in various directions. Having loosened one side, there was then no longer any difficulty.

With regard to the limit of 150 to 200 tons, he mentioned those amounts because they were approximately those to which he had worked up to the present. By using the 3in. machine he got, with full pressure on, about 120 tons. When using a 4in. machine he generally used about five pistons instead of eight, and he got 170 or 180 up to 200 tons pressure with that particular size. There was no limit. It was possible to increase the pressure according to the length and size of the machine, but there would arise a liability for the cartridge to become bent. There was no bending of the cartridge if the sizes of the machines used were limited as at present, provided that a regular hole was

obtained. If the hole was not regular and smooth there would be the risk of some damage being done to the machine. He did not mean to say that there was a danger of bending the machine after the material had once been broken. When the back of the material was broken there was no danger to the cartridge. Very few machines had been bent or damaged in anyway. That was probably due to limiting the length of the cartridge to 20in. in the case of eight-piston machines and a few inches less in the case of a five-piston machine.

With regard to varying the intensity of the pressure, he thought that that was hardly necessary so long as the hole was drilled sufficiently deep. He did not like to have the end of the cartridge anywhere near the end of the hole. It should be right in. As long as it was right in the hole there did not seem to be any advantage to be gained by varying the pressure. He got the cartridge right into the hole, and then it was not necessary to make any change. Usually the pistons were out an equal distance throughout the full length of the cartridge, showing that the resistance had been the same throughout its length.

7th December, 1914.

H. C. H. SHENTON, PRESIDENT,

IN THE CHAIR.

MECHANICAL APPLIANCES FOR THE PAINLESS KILLING OF ANIMALS.

By S. M. DODINGTON.

[Member.]

MUCH attention has been given of late years to the humane slaughter of animals, and numerous automatic killing appliances have been invented and are daily used in thousands of slaughter-houses. The help and criticism of engineers and mechanically-minded persons is, however, necessary to help forward a worthy reform. The first legislation for the reform of abattoirs was passed about 1896 in Switzerland and compelled the stunning of all animals before bleeding. Germany, Denmark, Finland, and Sweden gradually followed suit, and this practice also became fairly general in Holland, Norway, and, to a certain extent, in England. The stunning of animals by apparatus dependent on human judgment, skill and strength is unreliable and often cruel, and it was not until Dr. Sigmund, Director of the public abattoir at Bâle, invented a pistol for stunning cattle, that any real progress was made. Sigmund's invention was the beginning of better things, the earlier instruments being constructed after his idea.

General Aspect of Painless Killing.—A painless death—so far as we can ascertain—can be brought about in a fraction of a second by affecting the brain. People who have been stunned testify to having felt no pain from the blow, but only on recovering consciousness. In the case of animal slaughter, the blood is withdrawn after stunning, and death follows without recovery of sensibility. The author has seen almost every contrivance for stunning animals used in European countries and in North and South America, and is of the opinion that all weapons that are not automatically operated fail to produce instantaneous unconsciousness often enough to warrant their abolition, while, on the other hand, automatic instruments operated by explosion, springs, or compressed air are sufficiently perfect to justify their adoption. Every year sees an improvement in these automatic instruments, and their perfecting requires skill, patience and originality, and is therefore a task for engineers.

As regards taking life humanely by other means, anæsthetics are sometimes used on cats and dogs, generally in lethal chambers.

It is very questionable if this *is* a painless death, and until that is positively proved, great developments will probably not take place. This also applies to death by electric shock, which, as regards animals, has been tried only experimentally. Death by decapitation may be painless when skilfully applied, though some authorities state that as the brain is uninjured feeling still exists in the head for a few moments after it has been severed. Some years ago a guillotine for beheading poultry, acting horizontally by means of a spring, was exhibited in London ; it seemed to be an excellent and humane device, but is probably not much used.

The only remaining practical method of painlessly taking life is a reliable shooting apparatus, and this paper will deal only with such instruments.

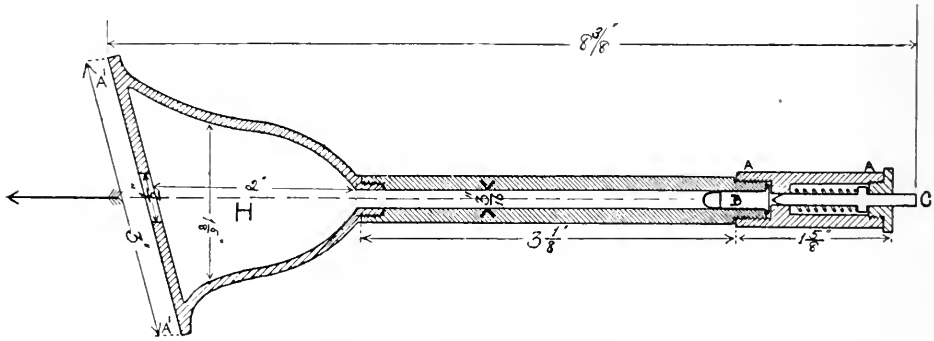


FIG. 1.—SIGMUND PISTOL.

Various Types of Pistol.—Dr. Sigmund introduced his pistol for use on cattle only (Fig. 1). The cap *AA* is unscrewed, a cartridge *B* inserted, the cap replaced, and the detonator *C* struck lightly with a small mallet. This causes the cartridge to explode, driving the bullet into the brain. The first instruments were combined with a leather mask to be strapped over the beast's head in such a position that the mouth of the pistol (which formed part of the mask) rested on the middle of the forehead. The mask was afterwards discarded, being of little value, and a silencing chamber *H* was added to reduce the noise of the report. The front of the silencer *A'A'* is frequently sloped so as to lie in such a position on the beast's forehead that the bullet strikes the medulla.

Fig. 2 shows Stoff's silencer. Note the muffling plate *AA* and the general arrangement of chambers. From 1894 to 1906 over four million animals were shot with Stoff's pistol. Modifications of this instrument are in use all over Europe, but those now extensively employed in Sweden are of a particularly neat and practical design, with the silencing chamber further improved, and the addition of a safety catch lever holding the detonator (after the principle of many telephone receivers) as a guard against possible accidents.

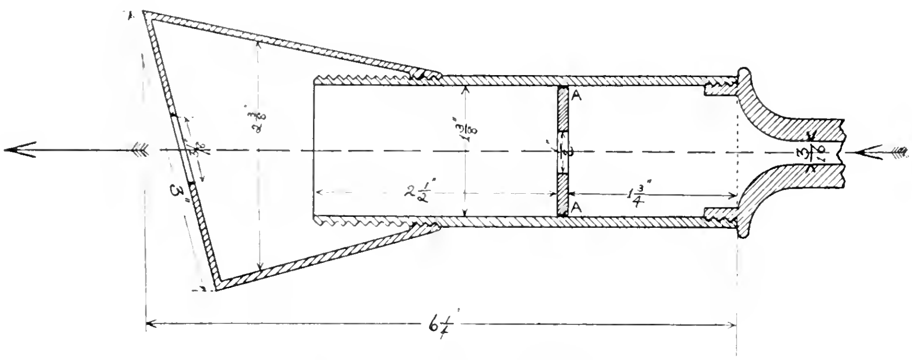


FIG. 2.—STOFF SILENCER.

There is a prejudice among some people against a bullet-firing apparatus, as the bullet may penetrate the head of the animal and strike bystanders. This can be overcome by using a soft-nosed bullet, which does not travel far after piercing the frontal bone.

In 1901 Frau Bolza offered £600 for providing prizes to encourage the development and testing of automatic instruments for stunning, and in 1902 a three-days' trial was held in the fine abattoir at Leipzig, where no fewer than 183 instruments were tried by a committee of experts. During 1902 and 1903 numerous trials took place also in Denmark, Austria, Hungary, Switzerland and Germany.

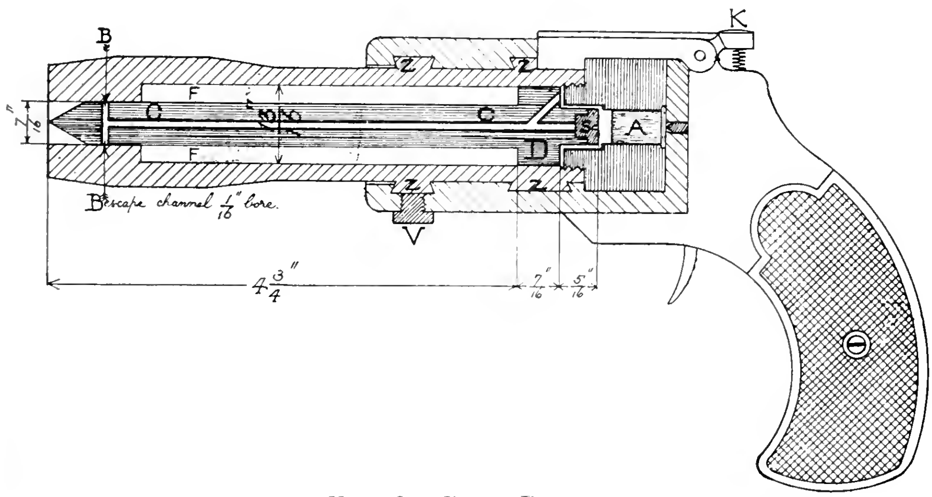


FIG. 3.—BEHR PISTOL.

Space forbids dealing with all the excellent instruments that are in use, but probably the best known and the most widely used is Herr Behr's pistol (Fig. 3), the principle of which is embodied in other makes, and which uses no bullet. The breach is opened, a blank cartridge *A* inserted and the breach closed.

The pistol is placed on the animal's forehead and the trigger pulled, causing the blank cartridge to explode, the expanding gases act on the piston *D*, which forms part of the bolt *CC*, forcing it into the brain. The gases travel along the hollow channel in the bolt and escape at the end through the two holes *BB*, also into the brain. It seems immaterial whether the exploded gases are discharged into the brain or into the atmosphere, different makers having different ideas ; the gases do not affect the taste of the brains, but what advantage there may be is doubtful, for the animal is stunned by the bolt, not by the gas. The air compressed at *FF* by the outward stroke of the piston reacts upon it, causing it to withdraw the bolt from the skull of the animal, the entire action taking place in a fraction of a second.

Trouble was sometimes experienced by the bolt adhering to the skull of the stunned and fallen animal, so Herr Behr devised a new type of pistol known as Model 5, which has been in use

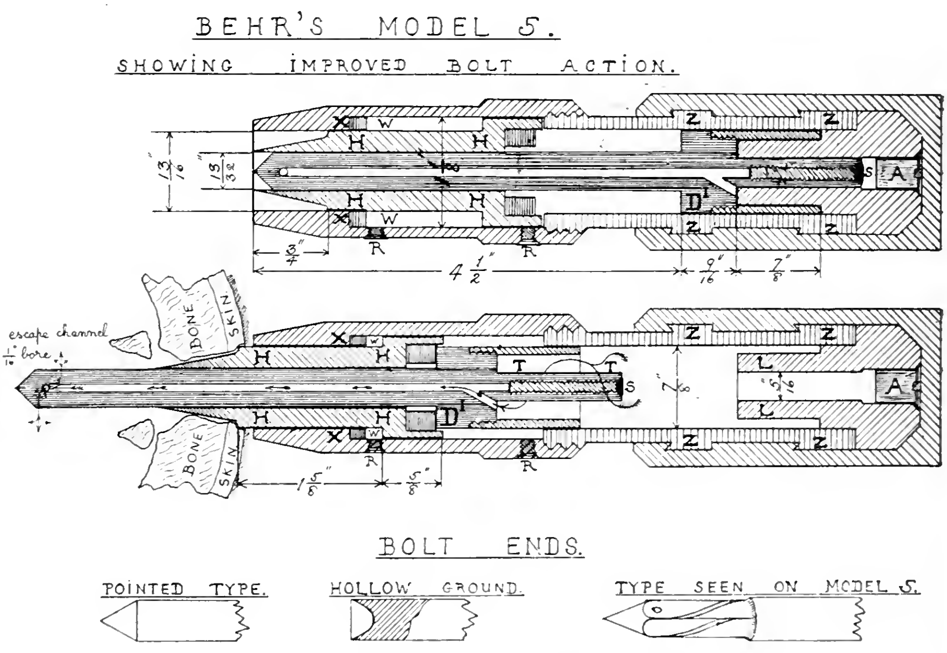


FIG. 4.—BEHR PISTOL (MODEL 5).

since 1913 (see Fig. 4). In Model 5 the piston *D′*, just before it completes its outward stroke, strikes the circular cutting cone *HHHH* which surrounds the bolt, causing it to enlarge the opening in the skull after the passage of the bolt, allowing the latter to withdraw easily by the usual compressed air cushion action. The air compressed at *WW* by the outward travel of the cone returns it into place. A rubber washer is fitted at *X* to assist air compression.

The breech action has been improved and is either fully ejecting or semi-ejecting. The powder used in the blank cartridges is without smell and very silent. The breech slides open like a drawer on guides *ZZZZ*, therefore it is encased on three sides. When the breech is open, the barrel, which works on a pivot *V*, can be turned. To open breech, press catch *K*, and push out breech left to right.

The measurements given in the working drawings of the Behr pistol are not necessarily the standard ones, and may be subject to slight variation. In Model 5 the explosive gases act with their full force on the piston tail rod *TT*, working in the collar *LL* at the early part of the stroke, before they begin to escape down the bolt and so out into the brain ; thus the full explosive force of the cartridge is utilised to drive the bolt through the skull. By removing the screw *S*, the escape gas channel can be periodically cleaned, and by removing the screws *RR* oil can be injected for lubrication when necessary. Herr Behr, writing to the author last May, stated that his pistol is used in 70% of German slaughter-houses, about 1,000 being in use in Germany and 200 in other countries, and that since 1903 about 6,000,000 cartridges have been used for cattle only, not counting smaller animals. Other statistics show that from 1903 to 1906 an average of 240,000 cartridges were used per annum, while during the year 1907 no fewer than 500,000 were used.

This excellent pistol is used very much for all classes of animals in Holland, Denmark, Germany and England. It would seem as though most of the German public abattoirs, of which there are about 900, would use it before long on cattle.

In 1912 Christopher Cash, Esq., B.A., of Coventry, who has made the introduction of humane killing in England his life work, and who is one of the greatest authorities on the subject, brought out his pistol. Previous to that date shooting was an expensive method, the cartridges sometimes costing over 5s. per 100. Difficulty was also experienced from the brains choking the escape gas channel in the bolt. This led Mr. Cash to plug that channel, and to bore a hole in the side of the cylinder, allowing the expanding gases to exert their full force on the piston for about a third of its outward stroke where most force is needed to ensure penetration, and then to escape into the atmosphere. Thus small cartridges could do the work of larger ones, consequently this pistol uses cartridges that cost only about 1s. 6d. per 100.

The hole in the side of the cylinder enabled the escaping gases to clear away the burnt products left in the cylinder from the previous explosion. Again, a very desirable result was obtained by slightly enlarging the piston area, which enabled the air compressed on the bolt side of the piston by the outward travel of the latter to exert a larger return force, and in every case

brought the bolt and piston right home again after firing. The bolt consequently never adheres to the skulls, even of the largest animals, and much trouble and complication is therefore saved. The pistol is even more silent than an ordinary air pistol, and the breech, which opens sideways and is of the simplest type, is automatically semi-ejecting. On account of the scavenging action of the escaping gases but little attention and cleaning are needed. Grease should be applied to the piston and bolt about every 30 shots, and a perfect air and gas-tight fit is obtained without the use of rings or washers provided that bolt and piston are greased. This pistol is designed for killing pigs, sheep and calves, but can also be applied to cattle, though a longer bolt and more powerful cartridge would probably have to be used for bulls and oxen.

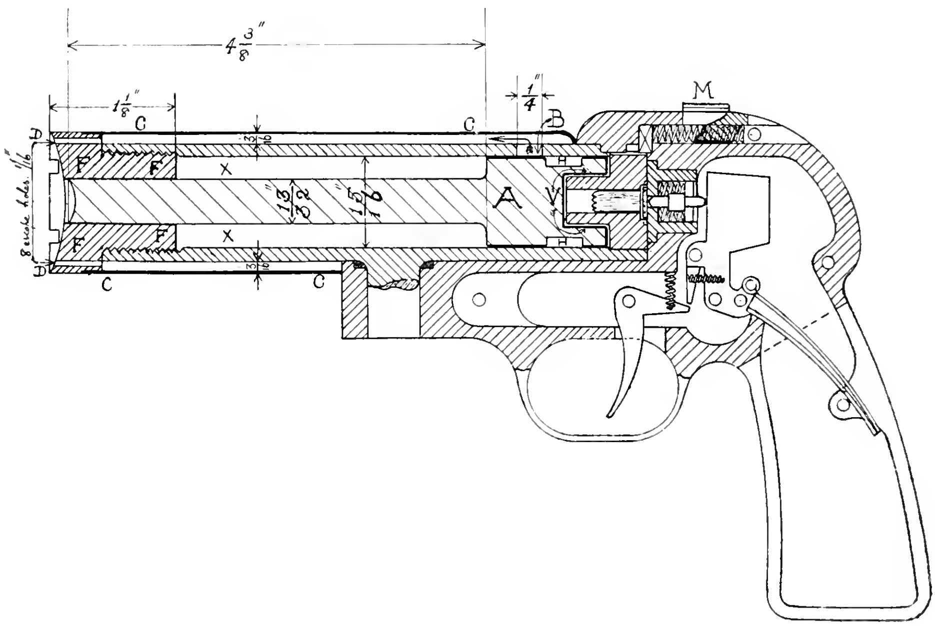


Fig. 5.—Cash Pistol.

Fig. 5 shows the principle. After the piston *A* has passed the port *B*, the gases escape into the hollow circular silencer *CCCC*, which surrounds the whole barrel, and pass out of the silencer through a number of ports *DD*, which are drilled in the nozzle of the barrel *FFFF*. The air compressed by the outward stroke of the piston at *XX* returns the latter with certainty and at a high velocity. It is estimated that the speed of the bolt is about 800ft. a second.

The groove *HH* in the piston is cut to retain the grease, and the hollowed-out end at *V* assists the gases to exert their full expansive force. To open the breech, draw back the catch *M* with the thumb and turn the barrel to the left. By unscrew-

ing the nozzle *F* with a key the bolt and piston, which are turned in one piece, can be withdrawn, and the silencer pulled off. The latter slides on over the barrel, and is held in place by the nozzle *FFFF*. The end of the bolt is ground hollow with a circular cutting edge. A thin nozzle can be slipped over the muzzle of the pistol, thereby lengthening the latter beyond the bolt, allowing of the later entrance of the bolt into the skull, thereby shortening the effective travel of the bolt in the brain. This is a useful acquisition for stunning very small animals, as it is unnecessary with the latter to have a full stroke.

Though not long on the market Mr. Cash's pistol is meeting with a good demand. Among many other places it is used at Messrs. Spear Bros. & Clark's bacon factory at Bath and Redruth, where about 700 pigs a week are killed. Their establishment is an object lesson in humane slaughtering. The pigs are driven into a pen, shot, and then hoisted by machinery and bled away from the pen. Death is painless, there is no squealing or struggling, and the live pigs are shielded from scenes of slaughter.

The author watched the slaughtering at this establishment, and without any difficulty, and with practically no previous practice with the Cash pistol, shot a number of pigs himself. The animals endured no physical and mental suffering as is so often the case.

The Cash pistol can be fixed at a right angle at one end of a special staff by means of an ordinary winged nut, which allows the pistol to be almost instantly fitted or removed. The staff has a spade-shaped handle at the end away from the pistol, also a trigger connected with a catch and wire to the trigger of the pistol. When a restive beast has to be shot, the pistol is affixed to the staff, and the operator is well clear of the animal's horns. The staff does not interfere with the loading or ejecting of the pistol in place.

Perhaps one of the most satisfactory instruments in general use for cattle is the R.S.P.C.A. humane killer (Fig. 6), introduced some six years ago by the Royal Society for the Prevention of Cruelty to Animals, to whom the greatest credit is due for having devised such a satisfactory and efficient apparatus. Nearly 3,000 of these killers are at work to-day in Great Britain. This killer was designed to allow the operator to stand away from the animal and at its side or partly behind its shoulder, Mr. Cash having followed up this idea in his combination pistol and staff.

To load, turn lever *E* downwards, remove the barrel *A* by twisting it a quarter of a turn right to left and pulling it out. Insert a cartridge in the barrel and replace the same by placing extractor *F* in line with lever E, push barrel home, and turn from left to right. Push lever *E* back after loading and before firing. Pull back hammer *G*, place mouth of silencer *C* on beast's fore-

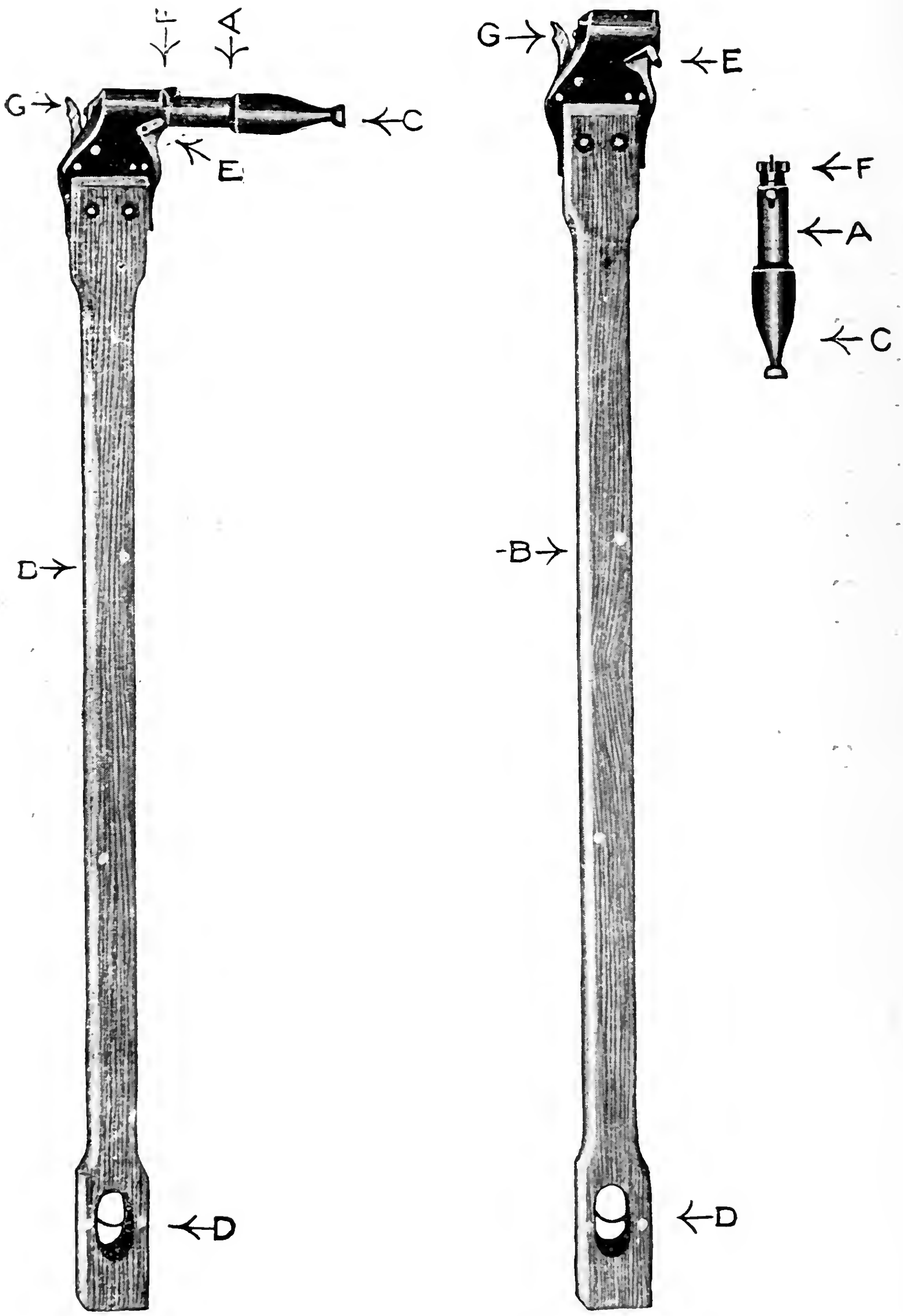


Fig. 6.—R.S.P.C.A. Humane Killer.

head and release hammer by trigger *D*, which is connected with former by wire running inside shaft. To reload, take off barrel as described, and remove old cartridge by pushing extractor *F* outwards, insert new cartridge and replace barrel.

The bullet is soft-nosed, and does not travel far after piercing the frontal bone. The barrel at *H* is rifled. This is a very powerful instrument, and can be used with advantage on very large old sows and boar pigs as well as the largest cattle and horses. Considering its power, it is very silent in action with the present form of silencer in use.

FIG. 7.—THE R.S.P.C.A. KILLER IN USE.

Professor Dahlstrom, of Stockholm, has devised a similar instrument for use on reindeer, and it is now coming into use in Sweden. In the latter country the public abattoirs are used as lecture halls and for demonstrations in humane slaughtering, and classes are given to butchers and farmers.

The R.S.P.C.A. have also designed a pistol for horse-slaughtering which could be used on all classes of animals if different strengths of cartridges were used.

The Future of Explosive Apparatus.—It is not improbable that bolt-firing pistols will be made repeating; it could be done, but with some complication, as the blank cartridges must fit to allow

the expanding gases to act on the piston. Before repeating bullet-firing instruments are introduced into public abattoirs more confidence must exist, and only reliable officials can be trusted. Firearms for killing domestic animals by a bullet lose a lot of their effect by the barrel being short ; were a longer barrel introduced, smaller cartridges could be used, costing about 2s. a hundred, and with probably over double the effect. The author has shot large pigs with an ordinary rifle, using the smallest cartridges. If these same cartridges were used in the ordinary short-barrel types of various humane killers the pigs would probably not have been stunned at all. Greater speed of handling and reloading must be attained, and probably the repeating pistol will have to come. In some of the packing houses in the States 1,000 pigs an hour are killed, and there is a wide field for the engineer to perfect the many theories in connection with humane killing.

Effect of Shooting on the Carcase.—This matter has been exhaustively thrashed out, mostly in England and Germany, and in the practically united opinion of experts no harm whatsoever to the carcase or serious injury to the brain is caused, nor is the bleeding retarded. In 1901 no fewer than 489 slaughter-house directors, veterinary surgeons, and veterinary high school and University professors assembled at Heidelburg public abattoir to test the effect of stunning animals before bleeding *versus* bleeding without stunning. About half the animals were bled while conscious, and the remainder were stunned by pistols, " Bruneau " striking masks and sledge hammers.

Nearly 99 % of the experts decided in favour of stunning before bleeding, preferring the shooting instruments. At the various trials that have taken place in Germany and England every gram of blood has been weighed ; the cut across the animal's throat measured to a centimetre ; the eyes of the animal photographed during bleeding and during stunning, and, lastly, the kinematograph is being used in the public abattoirs to take records, which are to be used to educate public opinion to the fact that legislation must be enacted to compel animals to be stunned with suitable instruments.

Instruments working by Spring Power.—About 14 years ago Herr Pilet, an engineer in charge of the plant at a Dutch abattoir, devised a spring gun for killing pigs. The muzzle of this gun was placed on the forehead, and the release, by trigger action of a strong spring, drove a specially shaped spike into the animal's brain. The spring was reset by fixing the gun by hooks on the wall and pulling back the spring with an arrangement exactly like a pump handle. These spring guns, known as the " Percuteur Pilet," are used in the best Dutch public abattoirs, but have made little headway outside Holland.

It is a praiseworthy fact that the best-ordered abattoirs in Holland use shooting apparatus entirely on all classes of animals, preferring the Behr pistol for sheep, calves and heifers, the Pilet gun for the pigs, and a modification of Sigmund's pistol for bulls, oxen and horses. The public abattoirs of Rotterdam and Amsterdam have also introduced shooting apparatus for large cattle and horses according to the last report, but a very different state of things existed when the author was last there, it being a matter of the greatest difficulty to get the large and capital cities to introduce modern apparatus, and the capital town of nearly every country is the reactionary in the slaughter-house, Christiania and Stockholm being notable and worthy exceptions, it would seem.

FIG. 8.—R.S.P.C.A. SPRING BOLT PISTOL.

Fig. 8 shows the R.S.P.C.A. spring bolt pistol, which is a great improvement, and, like all spring-working instruments, is independent of the cost of ammunition and the care that it requires. To set the spring, taking the lever in the right hand, place the slotted end of the lever on the foremost pivot and the

slotted end of the hinged arm on the hinder pivot. Hold the pistol with one hand against the knee, and with the other hand pull lever down and so press the spring home, where it engages automatically with the trigger. Hold the pistol by the butt, place it firmly on the animal's forehead, and pull the trigger. This releases the spring, which drives a steel bolt into the brain.

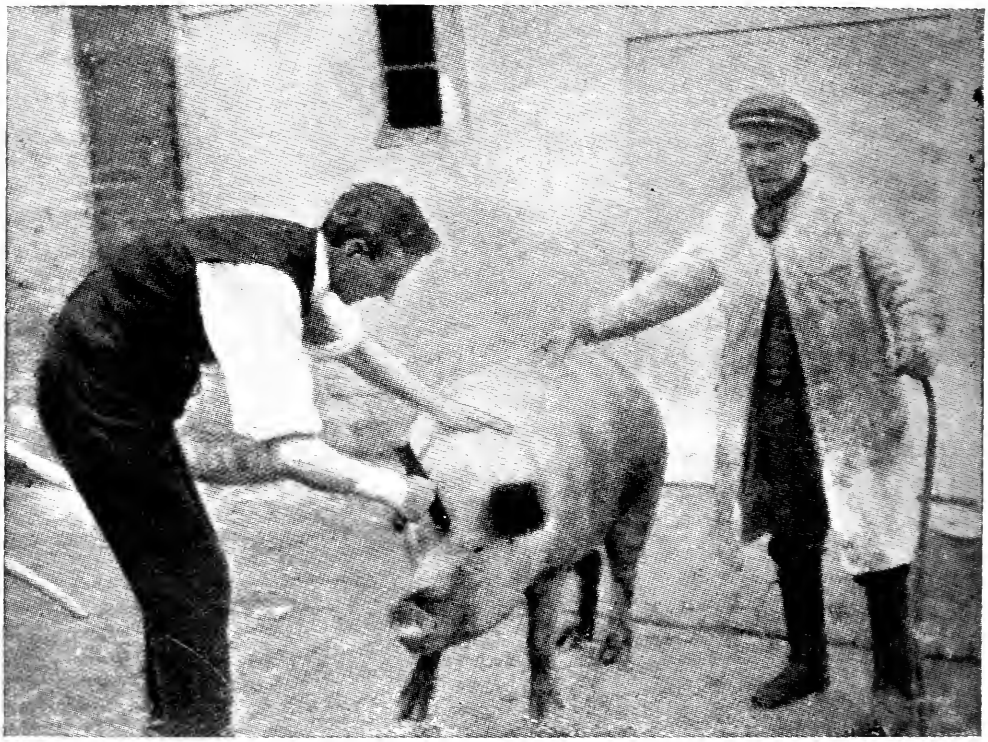


FIG. 9.—SPRING BOLT PISTOL IN USE.

Fig. 9 shows a captive-bolt pistol in use for killing a pig. For use on injured ponies in coal mines, where explosives are forbidden this pistol supplies a long-felt want. It is used already on ordinary cattle in one public abattoir in England, though it was really intended more for pigs and horses, the spring action having certain limitations ; with large cattle the bolt might fail to penetrate. The instrument must be very firmly pressed against the head, especially on releasing the trigger. The author has used this instrument on sheep, and it is perfectly satisfactory.

Instruments working by Compressed Air.—The Council of Justice to Animals, of 21A, Saville Row, Burlington Gardens, W., awarded the prize of £100 in 1912 (at a competition held at Islington abattoir for an improved slaughtering instrument) to Mr. Ransome for his pneumatic air killer. Fig. 10 shows this most ingenious invention, which consists of four essential parts : (1) the barrel with its chamber for compressed air ; (2) the traveller

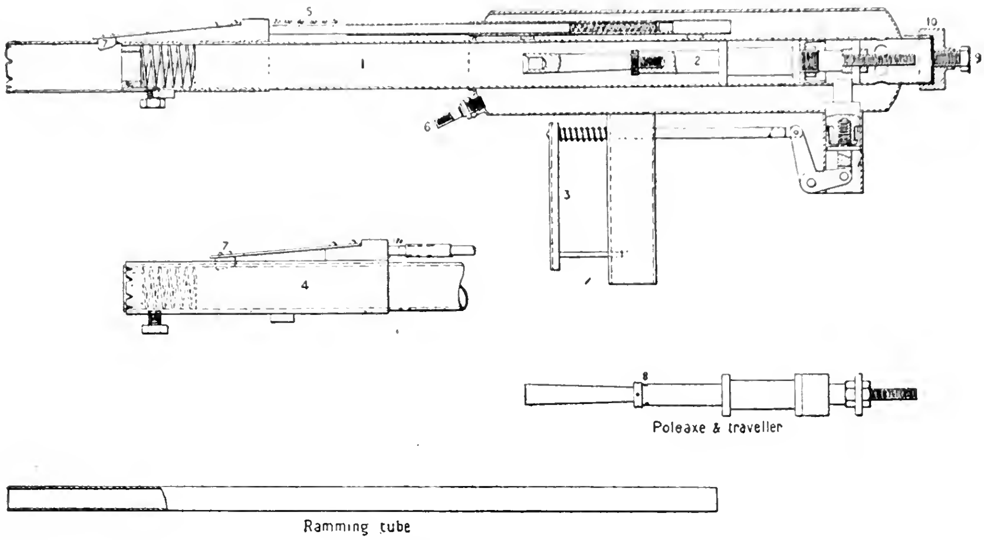


FIG. 10.—RANSOME COMPRESSED AIR PISTOL.

carrying the pole-axe ; (3) the trigger or releasing mechanism and (4) the combined extractor and pressure gauge. When the machine is loaded with compressed air, the traveller (2) is held back by the trigger, as shown, and the extractor (4) is held back by its spring catch. In use the muzzle of the barrel is placed firmly on the head of the animal, the trigger is gripped to release the traveller, which is driven forward with tremendous force by the compressed air. When the traveller reaches the end of the barrel it throws out the spring catch (7), and releases the extractor, so that, on the pole-axe entering the animal's head it is instantly withdrawn.

To charge the machine, remove valve cap (6), attach a motor tyre pump until correct pressure is obtained, which can be seen by gauge (5). When the machine is charged it can be repeatedly used without repumping as the compressed air is used over and over again, there being no escape except what may occur through leakage.

To load, insert the ramming tube into the muzzle of the barrel over the head of the pole-axe, point the machine downwards with the end of the ramming tube resting on the floor, grip the trigger handle, and press the machine downwards until the pole-axe and traveller is right back, then release the trigger to hold back the traveller and pole-axe, remove the ramming tube, and the machine is ready for use. On releasing the trigger the compressed air acts with its full force on the back of the traveller. The action of loading the machine (pushing home the traveller with the ramming tube), increases the air pressure by about 20 lbs. To reduce or release air pressure, partially unscrew valve cap (6), and press valve from seating. So far as is known this is the

first and only instrument using compressed air for humane slaughtering purposes. The following is the table of air pressures for use on different animals.:—

	Lb. per sq. in.
Cattle.	
Bulls	140
Bullocks and Cows	120
Calves (large)	80
,, (small)	70
Sheep.	
Rams (aged)	120
Sheep (ordinary)	70
Lambs	60
Pigs.	
Boars and Sows of 30 st. and over ...	120
Pigs (medium)	80
,, (small)	70
Horses	100
Dogs and Cats.	
Dogs (large)	80
,, (small)	60
Cats	50

The Ransome air killer has now been greatly improved, the air chamber having been made hemispherical, the better to withstand the air pressure equally on all points. The new globular air chamber is only 4½in. in diameter, and the barrel has been shortened; in fact, the whole apparatus is far more compact and handier than the original design.

Pens for Holding Animals during Stunning.—The ideal that is being aimed at is to stun animals in their natural position, if possible, without roping or tying them, and to segregate the live animal from scenes and smell of slaughter. Fig. 11 shows a stunning pen for cattle which, in various modifications, is much used in the English Colonies and in North and South America. It was constructed solely for practical reasons, allowing of speed in handling cattle and safety to the workers; incidentally it answers many humanitarian demands.

The door *X* is raised, a beast driven in and the door lowered. The stunning operation can then be carried out from platform *B* by the R.S.P.C.A. killer or with an ordinary rifle. Very troublesome beasts can, if necessary, have their heads steadied when in the pen by a rope secured round stanchion *D*. The side *AA* is then raised, and a shackle attached to the hind legs of the stunned animal, and it is then hauled up by electric motor on to an overhead runway bar, and bled some yards away. In America

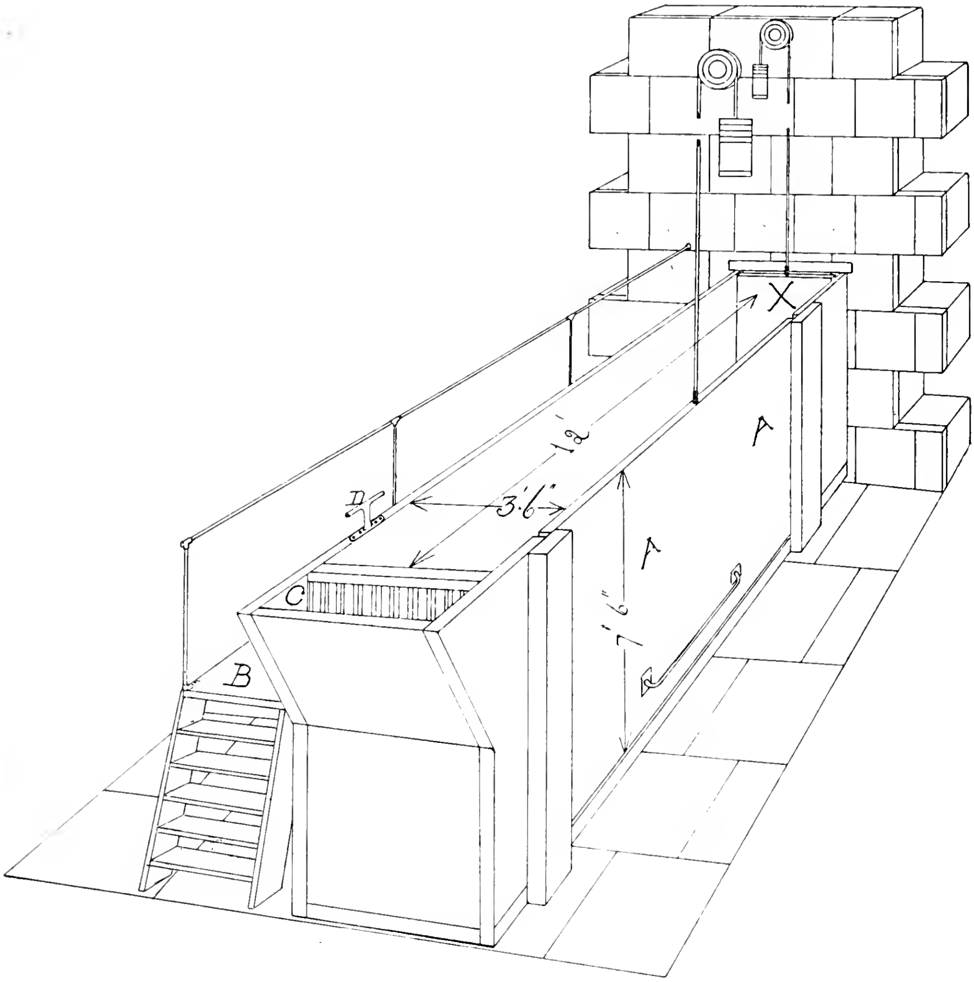


FIG. 11.—STUNNING PEN FOR CATTLE.

doors *X* and *AA* are frequently raised by motors. The door *AA* is then lowered, and the door *X* again raised, and another beast enters.

In South Australia the R.S.P.C.A. killer is being introduced for use on cattle in these pens and the authorities ask if the shaft of the killer can be made 2½ft. longer ; evidently the Australian pens are deeper than the American ones, and the animal therefore further below the operator. This system allows the beast to stand naturally without roping, it is shielded from sight of surrounding butchery, and the operator is safe. The beasts, however, do not enter these pens readily, and have to be prodded, frequently electric goads are used ; one would wish to avoid this opportunity for cruelty, which also causes serious loss of time.

The author suggests that in large abattoirs the waiting pens should be arranged in parallel rows with footways between, while at one end of the pens and at right angles to them could be a

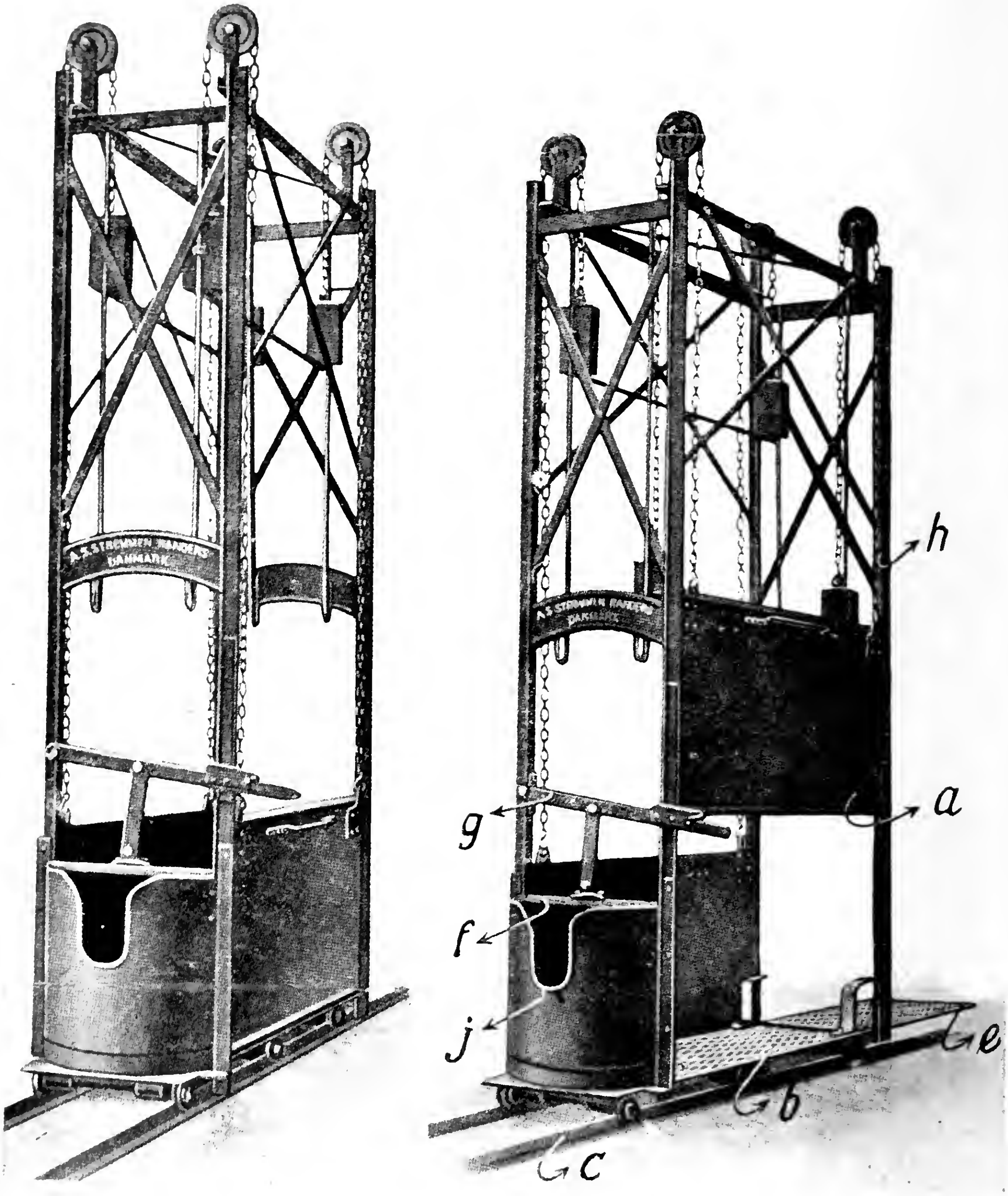


FIG. 12.—DANISH STUNNING PEN.

travelling platform driven by electricity and passing through the stunning pen inside the adjoining slaughter hall. The beasts would be driven from the pens along the intermediate footways to the moving platform at one end of the pens, and thence conveyed automatically in single file to the stunning pen. The floor speed should not exceed 30ft. per minute, and the floor should be set in motion only when it is desired to bring another beast into the stunning pen.

FIG. 12*a*.—DANISH STUNNING PEN.

A food rack might be added to the stunning pen in such a manner that the beasts only smell and cannot eat the food; this would tend to make them enter more readily, provided the pen and its surroundings are kept free from blood. The stunning pen could be outside the slaughter hall if desired, the moving floor being continued inside, so that beasts could be shot outside the hall and brought in after stunning.

Figs. 12 and 12*a* show the sort of stunning pens for pigs used to a certain extent in Sweden and Denmark, and the author believes, Finland and Norway as well; their use is increasing. The entrance door *e*, working on hinges attached to the bottom of the pen *b*, is lowered, so as to act as an inclined entrance slope; the pig is driven in, and the door *e* closed behind it and fastened with a clasp. By pushing the door *e* forward the bottom of the

pen (to which this door is attached) is moved forward also, carrying the pig with it, until the latter's jaws are resting on the mouth rest *J*, and the head is under a small hoop or bar *f*. The bottom of the pen rests on rollers, which run on rails *C*. Thus whatever the length of the animal, it is held perfectly steady for stunning, and that result is obtained without squealing or struggling.

The latest pens have the mouth rest *J* adjustable by means of a lever *g* to suit different classes of pigs. After stunning, the side *A* is raised, and the carcase rolls out ready for bleeding. By lowering side *a* and letting back door *e*, the pen is ready for another animal. The idea is good and answers well in practice. The pen shown in Fig. 12 is made by A. S. Strommen, of Randers, Denmark. It is a " double " pattern, and the stunned pigs can be ejected on either side.

Figs. 13 and 13*a* show the German pig pen, which handles a animals rapidly, has been well reported on, and increased the daily output at one bacon factory. According to veterinary surgeons, the flesh of animals stunned in such pens in their natural position is

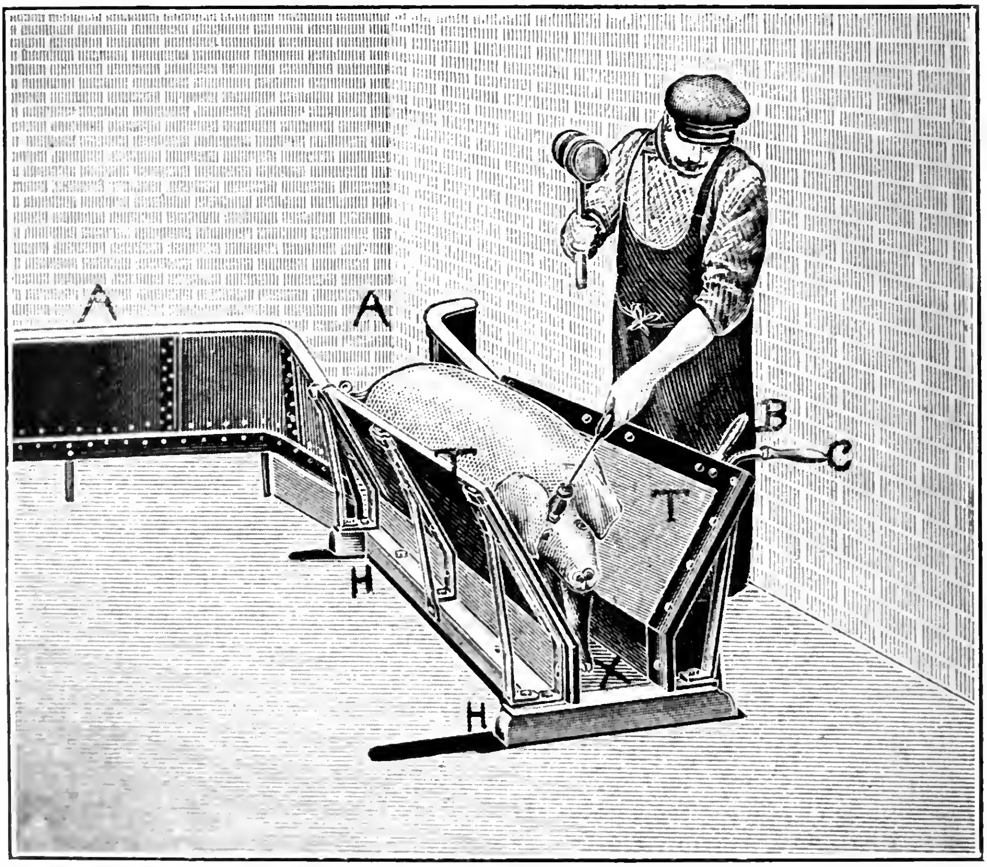


FIG. 13.—GERMAN PIG PEN.

firmer and keeps better. The pigs are driven into it one at a time through a suitable run *AA* ; they do not hesitate to enter as the pen is open at the far end from them. Animals generally shy at entering blind alleys, but in this invention that difficulty is absent. As soon as a pig passes between the V-shaped sides *TTTT*, a lever is pulled, which allows the floor of the pen *X* to open beneath its feet. The pig immediately finds itself resting on its stomach with its legs dangling through the narrow bottom. In this position it is stunned, and the pen, which works on hinges *HH*, is turned over, and the animal ejected for bleeding, the pen pulled back and the floor reset by another lever. *B* and *C* are levers for manipulating the opening and closing of the floor.

Final Suggestions.—The author suggests that a great deal of time and labour would be saved and a very great advance made in sanitation if all animals after stunning were hoisted by their hind legs and bled head downwards on the American principle ; the blood should be caught in white enamelled troughs with running water, and the stunning pens should be at least 50ft. away from

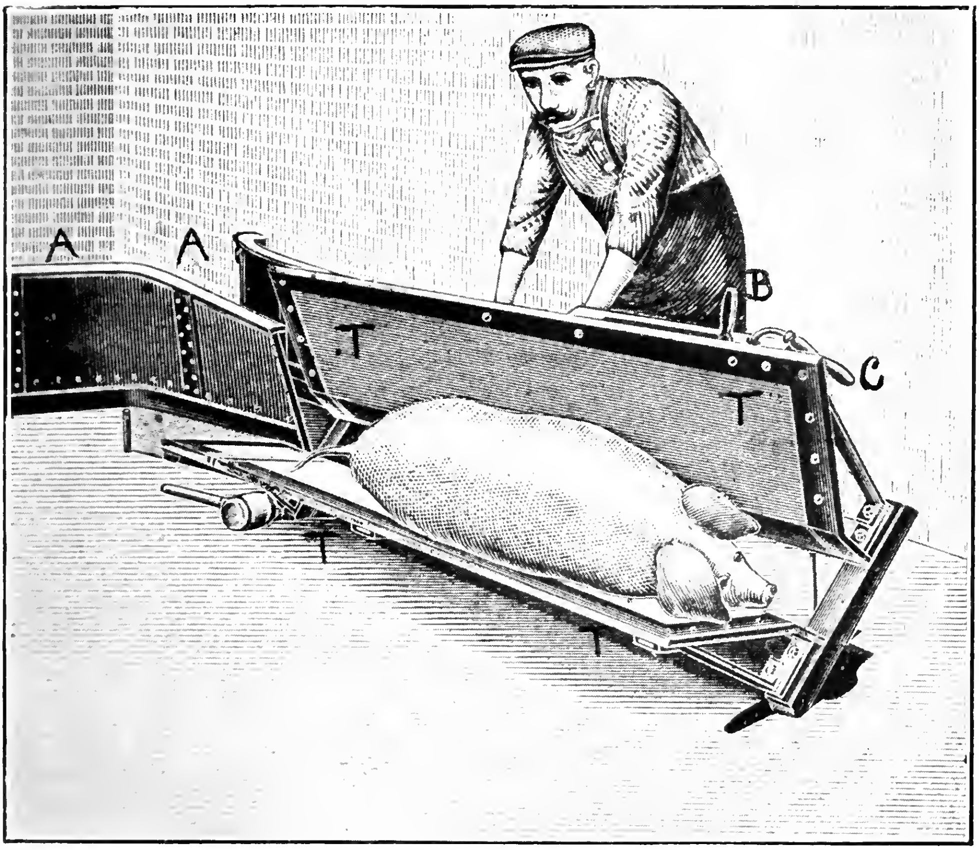


FIG. 13*a*.—GERMAN PIG PEN.

the bleeding and dressing operations; the carcases would run from the stunning pens to the bleeding troughs on overhead runways. The use of travelling floors, acting in conjunction with a practical system of stunning pens, would probably save a lot of time and rough handling of animals.

At the present day a thoroughly efficient pen is needed for all small animals, which will enable them to be dealt with at high speed; when such a device is on the market perhaps will be time enough to deal with the travelling floor idea. In small abattoirs no such great speed is needed, and the present day ideas answer fairly well, but they are probably out of the question for large establishments with the exception, perhaps, of the American "Knocking box" for stunning cattle, which latter has proved efficient and speedy in very large packing houses and meat works.

Fig. 14 is a suggestion by the author to obtain a higher state of sanitation and comfort and convenience for employees during the bleeding process and also to endeavour to obtain a more scientific and less wasteful way of handling the blood. This is a pen for sheep, pigs and calves, but the idea on a larger scale could be applied to beasts. After the animals have been stunned and hoisted on to the overhead runway they continue their journey by the travelling hooks *A*, and pass in between two metal walls *CCCC*, which are lined on the inside and at the bottom (which forms a trough) with white enamel, and over every inch of which a slow stream of water runs whenever one or more animals are hanging between the partitions. Here they are bled on entering the partitions; each animal comes from runway bar *X* and continues its journey on to bar *HH*. When one or more animals run on to bar *HH* the extra weight opens valve *F* through rod *E*, and opens water supply to cleanse partitions and trough through pipes *GGG* and *BBBB*, consequently water is playing as long as there are any animals hanging bleeding on bar *HH*.

As soon as the carcases are rolled along on to bar *A′A′*, the weight *D* overcomes the weight of the bar *HH*, and allows it to rise and close the water valve *F*. The bar *HH* works on a hinge at *W*. The water and blood run out of the trough through pipe *Y* into separator *R*, which might be worked like a cream separator, but which instead sends the water to the sewer and the blood into the usual drying and treating process. A long hook can be used to pull carcases along the bar *HH* between the partitions.

When animals are bleeding, even after stunning, reflex action is frequently very great, and can occur even when the head is severed. This system would obviate all splashing of blood and other inconvenience. At Offenbach public abattoir the walls of the slaughter halls are lined with marble, and water plays over the floors during working hours.

Next to humanity, perfect sanitation should be foremost in

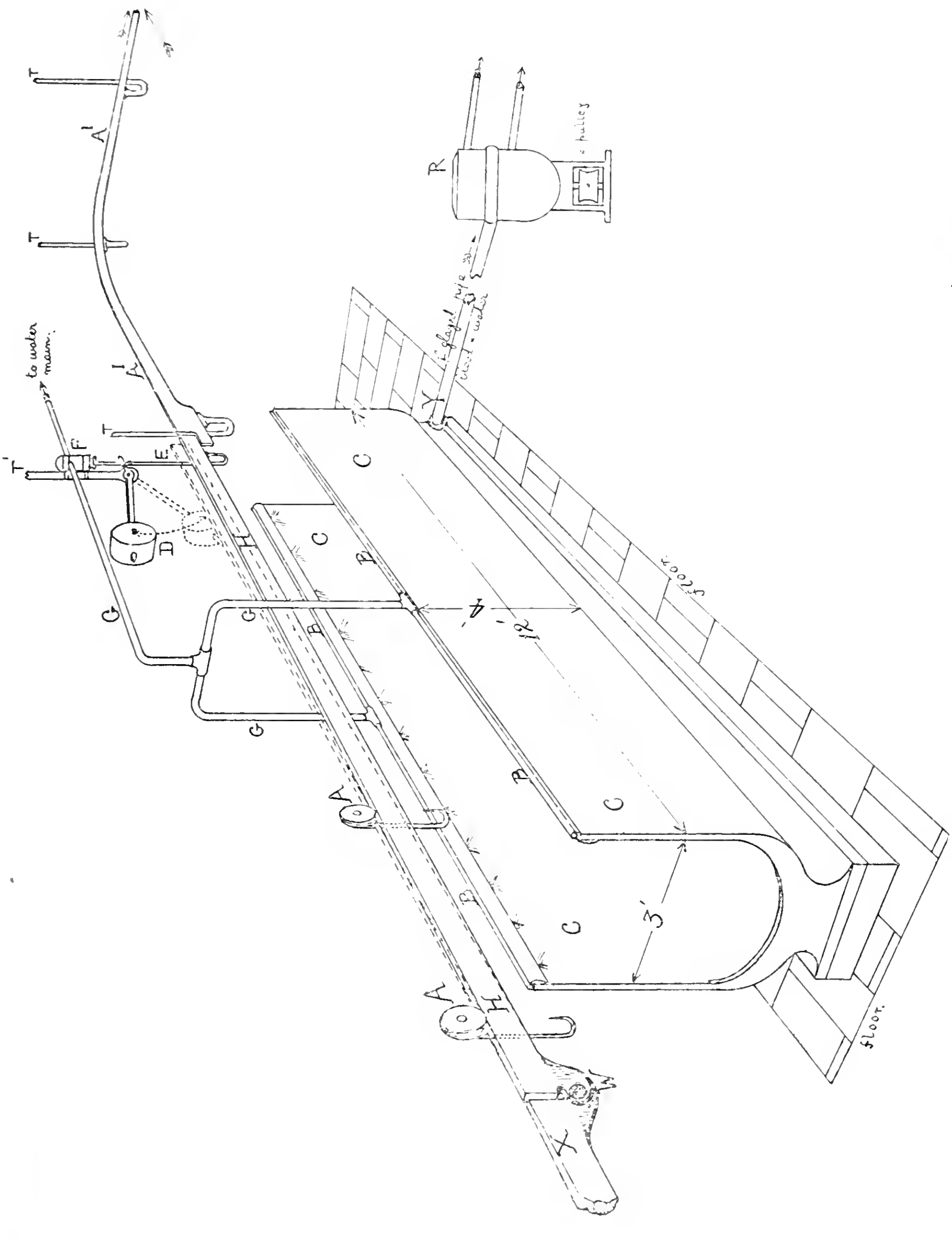


Fig. 14.—Suggested Sanitary Apparatus for Bleeding Animals.

the modern slaughterhouse, and the engineer has a wide field in which to exercise his ingenuity.

The author is indebted to the Royal Society for the Prevention of Cruelty to Animals for the loan of illustrations (Figs. 6, 7, 8 and 9); to the Council of Justice to Animals for a description of their air killer; to the firm of A. S. Strommen, of Randers, Denmark, and to Dr. Ramdohr, of Leipsig, for photographs.

He also wishes to acknowledge literature and kind assistance given by Herr Stoff of Erfurt, Herr Behr of Bremen, the various societies in Norway, Sweden, Finland, Denmark and Holland, and the directors of many abattoirs throughout Europe, particularly Director Hanson of Copenhagen abattoir, and his staff. Mr. Cash and Mr. Cotton of Coventry have also given the author much practical help for which he is grateful.

Discussion.

The **Chairman** said that, after the cordial reception which the meeting had given to the paper, he was sure that words were not needed from him to induce the meeting to give the author a very hearty vote of thanks for his contribution. The paper had given them very excellent examples of the appliances which had been invented for the painless killing of animals, and he was sure that there was no one in the room who would not desire that many improvements should yet be made. If animals which had to be slain could be slain painlessly, it would be a credit to all concerned. He would put from the chair that a hearty vote of thanks be accorded to Mr. Dodington for his paper.

The proposal was carried by acclamation.

The following written communications were read :—

Capt. J. W. Rainey, writing on behalf of the Director-General, Army Veterinary Service, said :—

"I am directed to say it is regretted that the present stress of work will not allow time for a delegate of the Army Veterinary Service to attend the meeting of your Society. For the same reason it is not possible to give you the considered remarks of the Army Veterinary Service in writing further than to say that destruction of horses is carried out in time of peace entirely, and in time of war as far as possible, by the Greener humane cattle killer. This instrument is on the principle of a pistol firing a bullet, in which the sound of the report is largely lessened by the passage of the bullet through a dome-shaped hollow space which acts as a silencer. This is useful in lessening the liability to stampede when a horse has necessarily to be destroyed in the vicinity of others. In war, when the cattle killer is not available, destruction is carried out with the service revolver. Both methods are equally instantaneous and painless. Whatever method is used, a certain slight knowledge of anatomy is necessary, as the bullet must, to ensure certain sudden death, penetrate the cranium above an imaginary line drawn between both eyes at the upper margins of the sockets. Best results are obtained when the bullet enters the medium line of the skull about an inch above the aforesaid imaginary line."

Mr. Arthur J. Coke, Secretary, "Our Dumb Friends' League," wrote :—

"My Society is, of course, a great deal in favour of humane appliances for instantaneous destruction of animals of every kind, and we should very much like to see a law passed that only humane appliances were to be used in slaughterhouses. We are strongly of the opinion that private slaughterhouses should be abolished and only licensed abattoirs permitted."

Mr. Edward Sewell, M.R.C.V.S., wrote :—

"I am quite in sympathy with the author's views. As far as the slaughter of horses and cattle is concerned in this country the old and barbarous method of the poleaxe is being rapidly superseded by mechanical appliances. In my opinion the use of the poleaxe should be absolutely prohibited by law, for no matter how skilful the user may be, the slightest movement of the head of the animal causes the axe to strike some other part of the head than that which was intended. Indeed, it has been my unfortunate lot to see some ghastly sights of this description, which made a great impression on me, and I have since never ceased to agitate for the total abolition of the poleaxe. The apparatus put forward by the R.S.P.C.A. is a very good one indeed, and answers the purpose well, but is in itself rather large and clumsy, and having such a long handle, the nozzle of the gun part is apt to slip slightly from the forehead. Personally, I prefer the smaller instrument of the Sigmund kind, and have frequently used Greener's Patent Cattle Killer. I find this appliance very effective indeed, the animal operated upon dropping dead at one's feet and seemingly without pain, the small pellet fired penetrating the most vital part of the brain. For small animals, like dogs and cats, which are easily controlled, chloroform is, in my opinion, the most merciful. They rapidly come under its influence and all is quickly over. In my own practice for small animals I use nothing but chloroform, and have now used it for very many years. To my mind to place a dog in a lethal chamber and choke it to death with carbonic acid gas, as is frequently done, is the height of cruelty, especially when a number are put in one cage, as I believe they are in some places, and fight and tear one another to pieces whilst the choking process is going on."

Mr. R. O. P. Paddison wrote :—

"Speaking generally, and judging by my own experience, which keeps me in constant touch with butchers who use humane killers regularly on more than 1,200 animals weekly, I consider it beyond doubt that instruments are now procurable which act quite efficiently and humanely, which any slaughterhouse hand

who is accustomed to handle animals can learn to manipulate in a few minutes; and that any animal, however large or however small, can now be humanely killed by means of one or other of these killers and without injury to the interests of meat traders.

"With regard to the design of these instruments, I should certainly say that some of them, judged by the test of long practice in the hands of average slaughterers, leave nothing to be desired. The killers firing bullets are simple in design, and rarely, if ever, get out of order or fail in their work even in the hands of the most negligent. Killers of the captive bolt type are much more suitable for all small animals, as they are safe for the operator, and damage to the meat or saleable portions of the animal is easily avoided, but their design is rather complicated, and they need some attention. Still, their manipulation is very quickly learnt, and very little care is needed to keep them in good working order. No doubt there will be improvements in the direction of simplicity, but this is not an urgent matter, as some of the existing types do their work reliably in the hands of average slaughterers, in illustration of which I may state that I have a pistol (or Cash killer) which has been used on more than six thousand animals, and is in perfect working order.

"The chief drawback to captive bolt pistols is that details of construction are not invariably perfect. There should be no real difficulty in having instruments properly tested as regards all these details before they leave the factory; but it is not easily practicable for a charitable society to make these tests satisfactorily before delivering the instruments to butchers. Yet a very vast amount of harm has been done and the employment of humane pistols has been much retarded by the delivery of instruments which have broken down owing to some mechanical defect easily preventible. I venture to hope that some members of your Society may give attention to this point as their practical knowledge would be of invaluable assistance to the charitable societies, which labour for the prevention of animal suffering in slaughterhouses."

Mr. Christopher Cash, opening the discussion, left the technical side of the different mechanical appliances to other speakers. He wished to thank Mr. Dodington for his very kind reference to the work he had done in producing such appliances. He also wished to thank him still more, in the name of those who were anxious for a reform of our methods of slaughter for bringing the question before such a Society. The question of mechanical appliances was a vital one, and it seemed to him that on their success depended the fate of the movement for reform. Mechanical appliances would never be what they should be unless they had the help of the best engineering experts in the country. The

opposition of butchers, which was the great obstacle to reform, had been based for some years past on the defects in the different mechanical slaughtering appliances. The butchers, it was true, objected also on other grounds, as, for instance, the effect on the bleeding of the carcase, but this objection had been met by the evidence of hard facts.

With regard to the mechanical appliances, they objected, firstly, on the ground of the danger of the bullet apparatus, and secondly, on the ground of the expense of the cartridges, but these objections had been met by replacing a bullet with a bolt and also by cheaper ammunition and a compressed air appliance. Thirdly, there had been complaints on the ground of want of reliability, and there he felt that the advocates of reform were not on so sure a footing, and it was exactly on that ground that he would invoke the aid of such engineers as were represented by the society. What was wanted was a slaughtering appliance so stable and so simple that it would drill a hole in the animal's head as easily as a tram conductor punched a ticket, and, until that was obtained, he did not think that their task would be considered as completed. If, in the discussion which ensued, anyone could give hints with regard to producing simplicity and reliability in appliances, it would be of great assistance.

Prof. G. H. Wooldridge (Royal Veterinary College) said that the question of mechanical appliances was in reality an engineering one into the detail of which he was not competent to enter, but he had something to say on the abstract question of the painless slaughtering of animals, with which he was whole-heartedly in agreement. The last speaker had struck the right note, particularly in his concluding remarks, with regard to the necessity for great simplicity in implements employed for the purpose. It appeared that the more complex the instrument the greater the risk of its getting out of order, and the greater the expense and trouble of putting it into order. Anything complex was not likely to meet with success, and the failure of the instrument day by day in repeated cases would bring the whole question into disrepute; slaughtermen would lose faith in the instruments, and then would refuse to use them.

With regard to the use of the different instruments, he was, for several reasons, at one with the butchers who objected to the use of bullets. In the first instance there was the danger to be considered to the people who were manipulating the animals. On more than one occasion bullets from such instruments as some of those that were displayed passed through the side of the skull after penetrating the brain, and they were certainly a source of considerable danger. Supposing that such a thing only happened once in ten thousand cases—and ten thousand

was not a very large number—it was once too often. Apart from that, they must bear in mind the extra damage done to certain parts of the head, which were valuable commodities. The author had suggested that soft-nosed bullets would remove that danger, but it was not at all certain that that would be the case. A bullet might not travel very far, but, as far as he was aware, there was nothing to prevent the soft-nosed bullet passing out. He understood that in those cases where it did not pass out it usually expanded, and that would only still further increase the injury to the internal parts of the head. He thought there was a better prospect before the captive bolt principle.

With regard to the effect on the carcase of stunning before bleeding, that was rather a big problem. It was not as simple as it at first seemed. If, in the stunning, certain centres, such as those which governed the circulation, were sufficiently affected and injured by the shock to stop the action of the heart at once, then the bleeding must be interfered with, and the result of that would be to reduce the proper setting of the carcase, which was vital from the meat salesman's point of view.

The author had said that there was some doubt as to whether anæsthetics were painless. He should like to ask on what he based that statement. The statement was, he believed, made particularly in reference to the smaller animals. His experience with regard to the administration of anæsthetics to the smaller animals, and to large ones also, but small ones in particular because of the greater ease with which they could be handled, was that anæsthetics properly administered were absolutely painless. He would like to know on what ground the author suggested that there was any doubt about the matter.

In the concluding page of the author's recommendations he suggested that the water and blood should be run through a separator, something like a cream separator, and that the blood would be driven off into one channel and the water into the other. Had the author any experience of that actually being done? because he (the speaker) had very grave doubts as to whether they would separate. A considerable portion of the elements of blood mixed directly with water, and, even supposing that by means of the centrifuge the red corpuscles and the solid bodies of the blood were driven in one direction, they would lose a very considerable portion of the liquid elements (serum or plasma), which would diffuse and gradually mix with the water as the blood was being carried to the separator. In that way they would lose a considerable amount of the albumen and other elements which were of considerable value.

He thanked the author for having brought the subject forward, and the Society for giving him the opportunity of being present. With regard to the perfection of the instruments it

was essential that the best engineering skill should be brought to bear, but at the same time the views of the practical butcher should be considered, because only by such a combination could the desired result be obtained.

Mr. Councillor A. C. Knight said that as a practical butcher he should like to thank the author for bringing this subject before such a body as the Society of Engineers, for he felt that if the members of the Society would put their practical experience to the test they would be able to produce that which practical men had been looking for for many years—a weapon which would be safe and reliable and simple in construction. Meat traders had found fault with many of the instruments which had been brought out from time to time, and which they had been told they ought to use instead of the simple instrument which they had used for many years with such effect. They were told that the poleaxe was not a safe and proper instrument to be put into the hands of men in their trade; but they claimed that reliable men put in charge of slaughterhouses were able to produce the painless death of animals with a poleaxe as certainly as with the other weapons. The other weapons had been known to fail, even during demonstrations. The butchers had proved with regard to the poleaxe that it was just as effective and more reliable in the hands of competent men than some of these instruments. Their objection to the bullet had been ably put before the meeting by the last speaker, viz., that it was a danger to those persons who used it. It had been proved that on more than one occasion the bullet had come out of the animal on the other side, and the members of the trade maintained that an implement firing a free bullet was not a proper weapon to be put into the hands of a man who had to slaughter an animal.

He thought that he might say that what the practical man in the meat trade was looking for was a weapon which would be simple, and which could be safely put into the hands of a slaughterer, and also one which was reliable and could not be easily put out of order. He felt sure that, when such a weapon had been produced and the confidence of the trade in it had been established, it would be found that the traders as a whole would use that weapon if it was an improvement upon the one they already used.

If there was any idea in the mind of anyone present that private slaughterhouses should be abolished—and he said this with reference to one of the letters which had been read—and if there was any idea that cruelty was practised in private slaughterhouses, he could assure the meeting, as one who had had to do with these matters from his boyhood, that he had never yet met with cruelty in a private slaughterhouse. And he would say now

publicly that the only cruelty that he had come across had occurred in public slaughterhouses under the control of, perhaps, the first corporation in the United Kingdom. They were bound to have from time to time among the number of men who killed animals one who was not up to high-water mark.

He thanked the author for having put the subject so clearly and brought it before the Society. It had been brought before the right body of men, and, if they would put forth their energies and give their attention to it he thought they would be able to do a great deal more good than other organisations had done, by reason of the policy pursued by the latter.

Mr. William Payne, as representing the National Federation of Meat Traders (Incorporated), which consisted of some two hundred affiliated associations of master butchers throughout the country, said that butchers were neither scientists nor engineers, but his Federation had repeatedly conveyed to the Royal Society for the Prevention of Cruelty to Animals and other bodies who were interested in the movement for humane killing that, immediately an instrument other than the poleaxe was produced which would not endanger the lives of their men or deteriorate the meat, they would be prepared to recommend it for general adoption. If such an instrument was produced it would not require any society to urge its use, for it would be sold " like hot cakes." The instruments which they had seen so far had been failures, but they were in hopes that, through the influence which the Society of Engineers could bring to bear, some instrument such as he had spoken of would be devised, and if so it would be very gratefully accepted and recommended.

Mr. M. G. Spindler (National Federation of Meat Traders' Associations) said that he wished to allude to the captive bolt pistol. He was a practical butcher, who had spent practically the whole of his life in the slaughterhouse, and he had on more than one occasion used a captive bolt pistol for slaughtering small animals, but up to that day he had not met with an instrument which, in his opinion, did the work as a butcher would desire. It was quite true that the pistols which he had used had successfully stunned the animal, but he had found upon making a post-mortem upon the brain that a considerable amount of hæmorrhage had occurred there. Butchers supplying the public were frequently called upon, under the direction of medical men, to supply their customers with sheeps' brains, and often the butcher was somewhat put about to find a sufficient amount of sheep or lambs' brains to execute the orders with dispatch. He thought that it was a great pity that a butcher should be invited to use instruments which were almost sure to destroy at least half of the brain.

At the Smithfield Club Cattle Show, Islington, his attention had that day been drawn to an improved captive bolt pistol, and he was glad to see the inventor, Mr. Cash, present. The explanation which had been given to him of the pistol had somewhat convinced him that it would be an extremely great improvement on those which he had previously used. There was something which could be attached to shorten the length of bolt which entered the skull. He hoped, when using this improved instrument, to find that much less hæmorrhage of the brain occurred, and therefore less waste of a valuable article of food.

Capt. Turner (Council of Justice to Animals) said that, to ascertain for himself whether animals were struck more than once, he went to Bermondsey, where the largest hide merchants were, and he got the proprietors of one of the largest places to allow him to see the hides as they were taken from the railway wagon straight from country butchers. Out of 126 hides which he examined about 29 had been struck more than once; 1 five times, 2 or 3 four times, several three times, and many twice. The rest had been lucky, and had only been hit once. The figures showed that nearly 25 per cent. of the animals had been struck more than once.

Mr. Knight asked the speaker whether he referred to the skulls.

Capt. Turner replied that he did. The hide showed more than one hole where the poleaxe had gone in.

It was said that stunning was done by the bolt and not by the gas, but he thought that the gas had a good deal to do with it. With the captive bolt pistol, where the gas went right through into the brain, he found that there was less action afterwards than there was with the Behr pistol, where the gas escaped at the back of the bolt and did not go into the brain. The captive bolt pistol made a very dark mark on white paper on a board where the gas had gone in, and in the other case the paper was quite white, showing that the gas had not penetrated.

He was talking to a professor of the Royal Veterinary College about animals being stunned by the bolt and the gas, who told him that he went to see some friends in the country who had an old pony which they wanted to have killed. He took the pony at ten paces, aimed at him with a gun, and as he was aiming the pony walked straight up to him, so that when he fired he was only a few paces away, the result being that the head split right open and the brain came out. That was not caused by the shot, because the closer it was fired the smaller would the hole be; it

was due to the column of gas which followed the charge into the head and expanded. That went very much to prove that the gas had a good deal to do with the stunning besides the action of the bolt.

The captive bolt pistol of the R.S.P.C.A. was an excellent pistol. It stunned better because some amount of gas got into the brain, but it was not quite so nice in one way as the Behr pistol because in the slaughterhouse part might get clogged with blood and be difficult to clean.

Some said that pithing did not cause unconsciousness, but he thought that some of the best veterinary authorities considered that it did. In order to make pithing better, it occurred to him once to get an instrument made with a sharp spear head adapted to the captive bolt pistol. On its being fired into the pith it would cut right through the bone and drop the animal at once. If pithing did not cause unconsciousness—and he believed that it did—such an instrument would be a very good thing. The only drawback that he found was that a butcher or anybody else might not always fire in the right place, and consequently would not get into the pith at all, so he put the appliance aside.

With regard to the danger of the bullet going astray, with the R.S.P.C.A. instrument he had never heard of any such instance. He supposed that that instrument and the Greener were far more in use than any other. The instrument was so heavy that it would not very well shift, and if they got it against the animal's head the bullet was almost invariably found somewhere in the skull.

With regard to the Greener, the reason why accidents had happened was that it was shaped to go close to the animal's head, so that the bullet should go straight into the medulla, and he thought that there could be no question that, where accidents had happened, people had held the appliance sideways instead of in the proper way, and naturally the bullet went out at the side of the neck. This was not the fault of the instrument. The Swedish instrument that the author remarked on had no silencer, and it was very noisy indeed. The Stoff pistol had a silencer, as the Greener had, and was equally good. He had tried the penetration of different instruments with a $4\frac{1}{2}$ in. plank, and the Greener had gone right through and into the ground underneath it. The Cash pistol, invented by Mr. Cash, of Coventry, was certainly the most excellent weapon he had ever seen.

The air killer which belonged to the Council of Justice to Animals was invented by a motor engineer named Ransom. The diagram in the book showed a former pattern which had been altered. It was proved that the long cylinder would burst sooner or later, although it might last for two or three weeks.

He was quite convinced that there was some mechanical fault about it, and a mechanical engineer who was consulted about it discovered that the shape was wrong, and he suggested the cylindrical shape, which did not burst or lose air. This machine is now perfected, and will be on the market very shortly.

As Prof. Wooldridge had said, there was great objection to interfering with the action of the heart, but that was too big a question for him to say anything about, because he did not understand it sufficiently.

Councillor Melluish (President of the Incorporated Society of London Meat Traders) said that he thought that Prof. Wooldridge had put the case for the meat traders as well as any speaker. With regard to the last speaker, he only brought out the fact that carefulness was necessary whatever instrument was used, and that there was nothing to be said even against the poleaxe if it was carefully used. As the Secretary of the Society of Meat Traders had just stated, if an instrument could be devised which was simple and safe for persons working in a slaughterhouse, butchers would be pleased to use it. He (the speaker) had killed animals every week for something like twenty years, and he certainly was not the cruel monster which some butchers were pictured to be. He had taken an intelligent interest in other matters besides butchering. Animals had to be slaughtered for human food, and butchers, speaking generally, were as humane as any class in the community.

The conditions in this country were different from conditions on the Continent. There was no imported meat in normal times on the Continent, and there they had to slaughter their own animals. He believed that he was right in saying that in this country something like 50 per cent. of the meat consumed was imported. The other 50 per cent. was distributed through the small provincial towns and villages, and, of course, some of it came to London. The meat had to be killed in small places which could not go to the expense of palatial abattoirs with marble walls and the latest scientific arrangements. He believed that very few abattoirs were self-supporting. What was wanted was an instrument which could be used under present conditions and which fulfilled the requirements which Prof. Wooldridge had so ably put before the meeting.

Mr. L. Y. Squire said that he was present that evening because the Secretary of the R.S.P.C.A. was unfortunately unable to attend. He felt that this meeting was one of the most important that had been held on the subject, because they were in touch with mechanical engineers who could by their advice and knowledge help enormously. It had been said that evening that when

a perfect instrument was invented it would sell like hot cakes. Perhaps instruments were not quite perfect yet, but they were the best obtainable. It must be remembered that if people had been waiting for the perfect bicycle no one would have ridden a bicycle before it had a free wheel and a back-pedalling brake. Meat traders had to make a start and do the best they could with the present appliances, and look forward to improvements. There would always be something new coming out, but that was no reason why they should not do a lot of good work with the instruments which they had now. However the captive bolt pistol was used it could not be said for a minute that there was danger to life and limb, because there was nothing to hurt the man operating. With regard to accidents with killers during the last four or five years, he had made it his business, whenever there had been an accident in any part of England or Wales, to find out all about it at once ; and he had not yet traced a fatal accident to any of the killers advocated by the R.S.P.C.A. To begin with, the soft-nosed bullet did not travel. Any person could go down to a slaughterhouse to-morrow and try the killer, and he would find that in nine cases out of ten the bullet expanded, and that when the horns were chopped off it would be found at the base of the brain. The humane killer which had been shown was not a dangerous instrument for that reason. He admitted that it was expensive because of the cartridges, which worked out at about $\frac{3}{4}$d. to 1d. a bullock. His Society would welcome all the mechanical engineers that could possibly come to their place to make suggestions of any description or to bring forward any theories. The R.S.P.C.A. would spare no time, trouble, or expense in experiments, their great object being to mitigate animal suffering, because they looked at the question from the animal's point of view.

The **Chairman** said that, before calling upon the author to reply, he would congratulate the meeting upon having had a very interesting discussion. In the first place, they had had views put forward on the one side by Prof. Wooldridge, Capt. Turner, and Mr. Squire, and, on the other side, they had had the vested interest of the trade represented by gentlemen who said that as soon as a perfect instrument was evolved they would at once take it in hand. The last speaker gave an apt illustration from the case of the bicycle, but could they not go farther and speak of the motor omnibus ? The public took to that vehicle before it was the perfect instrument of to-day. As soon as it was found that the trade would take up an instrument which might and would be the means of mitigating the sufferings of animals when they were being killed, it would be found that inventors would flock towards the engineering aspect of the matter and try to improve the apparatus now on the market.

He did not know whether the last speaker meant it as sarcasm when he said that the meat trade would object to $\frac{3}{4}$d. or 1d. a bullock for securing the painless killing of the animals, or whether it was a fact that such a price would be prohibitive. (No.) He hardly thought that that was the case.

They had had the views on both sides of the subject placed before them, and engineers, no doubt, would take the matter up earnestly and energetically, because if the thing was to go " like hot cakes " there would be a fortune in it for somebody.

A slight reference had been made to public abattoirs as against private slaughterhouses. That was a point on which a discussion might go on for hours. Both sides of the question might be very ably argued, and there might be good and bad points. As an engineer responsible for the administration of a large district where private slaughterhouses existed, he did not think that it would be good policy on his part to express an opinion one way or the other ; but if public slaughterhouses were managed in the way in which he saw one of them being carried on not many years ago, then he would say that there was a great improvement required in them. But, at the same time, there were many disadvantages in having private slaughterhouses in close proximity to dwelling house or residences.

Reply.

Mr. S. M. Dodington, in reply, said that the discussion had been most interesting to him, and he had learnt a good deal from it. According to careful reports which he had studied during the last year or two there had been about three serious accidents in the last twenty-five years with bullet-firing instruments. Millions of animals had been killed in that time. The reports included, roughly, all Europe. One accident was in Sweden, there was one the other day at Bedford, and one had occurred in Germany. He did not know how many others had occurred. As far as he knew, the accidents seemed to be in every case through the fault of the operator. Bullet-firing instruments were nearly always used on big animals. They should have their heads in line with the necks. It was very foolish in slaughtering to put a Greener or R.S.P.C.A. instrument or any other on the forehead if the head was turned round. He was not a slaughterman, but he had a great many years of experience with humane killers as well as with the usual instruments, and knew a great deal about it from the practical side, but he had never seen an accident.

Old friends of his, butchers in the West of England, had used the Greener killer for twenty-two years. One man the other day used a cartridge twenty-two years old, and it brought down the bullock at once. His friends would not be without that instru-

ment. Some of them had said in the past that there was nothing like the poleaxe because it never missed, but a few months ago they said, " We do not use the poleaxe any more but the humane killer. With the poleaxe we sometimes had to hit five or six times " ! ! A good man very seldom failed with the poleaxe in killing large beasts, but there was a lot of cruelty in the killing of pigs.

He had seen the very best men all over Europe in the best public slaughterhouses where they were nominally fined three shillings if they did not stun the pig at the first blow, but, notwithstanding that, in some of the public abattoirs they made 18 to 20 per cent. of failures. In one public slaughterhouse he was in recently each pig received about three or four blows. Public abattoirs when well managed were, from the humane point of view, superior to private slaughterhouses, but private slaughterhouses when well managed were superior to many public abattoirs. He had been to public abattoirs in some parts of Europe where things were managed properly, but he had also been into some where there was a great deal of cruelty. The public abattoir was a very good thing, but there was nothing worse on earth if it was not well managed, and he should be very sorry to see more abattoirs on the designs of some of the old ones.

With regard to the poleaxe and pithing, Prof. Wooldridge had mentioned that shooting with a bullet affected the bleeding. If they poleaxed an animal and put in a cane and broke up the medulla, the bleeding was affected just as if they took a rifle or a pistol and shot the animal in the forehead, the bullet going into the medulla. It did not make any difference. People seemed not to be quite certain as to how far it did affect the bleeding. The nerves indirectly controlling the bleeding through heart and lung action were centred in the medulla, and when that was broken up, the action of the heart and lungs was hindered and the expulsion of blood from the body to a certain extent. Most butchers in the country who used the humane shooting apparatus did not put in the cane because they did not believe that it was any good. In London, Birkenhead, and all the big cities they put the cane in afterwards and got just the same effect as with the bullet, the medulla being broken in every case.

In one or two towns in Canada they had a lethal chamber for dogs. The dogs seemed to suffer a good deal, and took a long time to die. A good many years ago in London an abattoir society experimented with a lethal chamber into which they put sheep and filled it with carbonic acid gas, but the sheep jumped about and seemed very unhappy before they died.

Prof. Wooldridge said that carbonic acid gas had never been suggested as an anæsthetic. He had referred to the sentence in

the paper which said that the question whether the use of anæsthetics was painless or not was open to doubt. He had not been talking of the use of the lethal chamber.

Mr. S. M. Dodington said that he had been chloroformed three times and had found it most unpleasant, and that if he had to be killed he would choose the ordinary pistol, which was instantaneous in its effect. How far anæsthetics were painful or otherwise was a thing which they were trying to find out. It was a very interesting study, and no one seemed to be quite certain upon the point.

His idea of a blood separator was only theory, and he had merely put it down for what it was worth. What he had said was purely suggestive, and he had wanted to hear someone who knew something about the subject. Therefore he was glad that it had been discussed. If they could separate the blood and water it would save a lot of trouble in flushing. He had no technical knowledge of the components of blood, and he did not know whether what he had suggested could be done or not.

With regard to the nozzle on the Cash pistol being a great improvement, he believed that it was, especially for animals such as very small pigs. An inch and a quarter stroke was a sufficient amount for these small animals.

He had seen hundreds of animals shot with the Behr pistol and with the Cash instrument, and he did not see much difference. They wanted to prevent the small channel such as the Behr pistol had from choking, and to get as simple a thing as possible.

ANNUAL GENERAL MEETING.

The Fifth Annual General Meeting of the Society was held at the Offices, 17, Victoria Street, Westminster, on Monday, December 14th, 1914, at 5.50 p.m., the President, Mr. H. C. H. Shenton, being in the chair.

The notice convening the meeting was taken as read.

The Secretary read the Report of the Scrutineers on the result of the Postal Ballot for the election of the Council and Honorary Officers for the year 1915 (p. 348). The awards of premiums made by the Council in respect of papers published in the Journal during 1914 were announced (p. 347).

The Report of the Council was read and adopted (see next page).

Messrs. Begbie, Robinson & Cox, Chartered Accountants, were re-elected as the Auditors of the Society on the motion of Mr. Burnard Geen, seconded by Mr. A. T. Bean.

A vote of thanks to the Council and Officers for 1914 was proposed by Mr. G. Noble Fell, seconded by Mr. H. Laurence Butler, and carried unanimously, the President responding in suitable terms.

A vote of thanks to the Scrutineers, Messrs. G. Noble Fell and Ernest King, for their services in connection with the postal ballot for the Election of the Council for 1915, was passed.

The meeting closed at 6.15 p.m.

REPORT OF THE COUNCIL FOR THE YEAR 1914.

In presenting their fifth Annual Report since the amalgamation and incorporation of the constituent Societies, the Council have to state that at the date of this Report the membership of the Society was as given below :—

Hon. Fellows	24
Fellows	55
Members	318
Associate Members	180
Associates	13
Total	590

There are also about 100 members of student Societies affiliated to this Society.

The Council have to record with deep regret the deaths of Mr. Tom Edward Bower, Vice-President ; Mr. George James Crosbie-Dawson, Fellow (Hon. Treasurer of the Civil and Mechanical Engineers Society from 1860 to 1869) ; Mr. Arthur Rigg, Fellow (President in 1884 of the Society of Engineers) ; Mr. J. B. Walton, Fellow (President of the Civil and Mechanical Engineers' Society, 1870-71) ; Mr. H. F. Petter, Fellow ; and Mr. Leslie Boddington, Associate Member.

Meetings.

In addition to seven Ordinary Meetings of the Society, the Council have met 10 times during the year and there have been 30 meetings of the various Committees.

Visits.

During the summer vacation, visits were made by members and their friends, as follows :—

May 27th. The Laboratory of M. Emile Bachelet (Bachelet Levitated Railway).

July 28th. The Royal Doulton Potteries, Lambeth, S.E.

Alteration of Articles and By-Laws.

The Council have for some time past had in view the desirability of making certain modifications in the Articles and

By-laws. In order to effect the necessary alterations to the Articles of Association a Special General Meeting was held on Monday, October 5th, when the proposals made by the Council were approved by the members and these proposals were confirmed at a Special General Meeting held on Monday, November 2nd, 1914.

As regards the alteration of the By-laws a postal ballot of the members is being taken in accordance with Article 45 and By-law 7, the result of which will be known early in 1915. Copies of the revised Articles, By-laws and List of Members, will be sent to members as soon as they are ready.

The War.

Several of our members have responded to the call for men and are now serving in the Allied forces. The following are those whose names have been ascertained up to the present :—

H. Colin Allen.	Lieut., 6th Battalion Wiltshire Regt.
R. W. A. Brewer.	Lieut., Mechanical Transport Corps.
G. E. W. Broade.	2nd Lieut., R. E. Reserve of Officers.
L. Bryan.	3rd Battalion Birmingham Regt.
M. H. J. Bunny.	French Army.
S. W. Clark.	3rd Battalion Wiltshire Regiment.
Arthur Easton.	Major, 4th East Yorkshire Regt.
M. E. FitzGerald.	South Midland R. E.
M. E. Gérard.	French Army.
J. R. Gwyther.	2nd Lieut., 3rd Manchesters.
G. R. Harrison.	Canadian Contingent.
H. C. Hawkins.	Lieut., 6th Batt., The Welsh Regt.
W. Holttum.	Lieut., 1st Reserve Battalion, City of London Royal Fusiliers.
Henry O'Connor.	Lt.-Colonel, Forth Royal Garrison Artillery.
E. Scott Snell.	Lieut. Army Service Corps, T. F.
R. D. Thomas-Jones	2nd Lieut., R.E.

No doubt other members are serving in the naval and military forces and the Council hope that they, or their friends, will send in their names for publication, mentioning their rank and the name of the unit with which they are serving.

The available reports of the fighting that has taken place up to the present emphasize the important part taken by the engineer in modern warfare, not only in devising and utilizing means of offence and defence but also in connection with mechanical transport, aerial reconnaissances, sanitation, and other auxiliary services.

Finance.

The Balance Sheet and Income and Expenditure Account for the year ended 31st December, 1913, were audited by Messrs. Begbie, Robinson & Cox, Chartered Accountants of 3, Raymonds Buildings, Gray's Inn, W.C., and were published in the Journal for March, 1914. The Balance Sheet showed a reduction in administration expenses, and although a larger amount than usual was written off for depreciation of furniture, etc., the excess of Income over Expenditure was £9 13s. 1d. The Council consider the financial position of the Society satisfactory.

Papers and Premiums.

The President, Mr. H. C. H. Shenton, on February 2nd, delivered his Inaugural Address, which dealt with the organization of the engineering profession and the position of the consulting engineer, and also gave an outline of recent progress in water engineering, sewerage and sewage disposal.

The thanks of the Society are due to the following gentlemen who have contributed papers for reading at the meetings or for publication in the Journal during 1914 :—

Mr. A. S. E. Ackermann : "The Utilization of Solar Energy."

Mr. A. S. Buckle : "Cylinder Bridge Foundations in the East, and the Construction of the Sittang River Bridge, Burma Railways."

Prof. Herbert Chatley : "The Dynamic Increment of a Uniformly Distributed Load."

Mr. R. H. Cunningham : "Irrigation in India."

Mr. S. M. Dodington : "Mechanical Appliances for the Painless Killing of Animals."

Mr. T. J. Gueritte : "Esperanto : an International Language for Engineers."

Mr. A. B. Howes : "Trade Unionism as applied to Professions."

Mr. E. Kilburn Scott : "Electric Lighting of Steam-driven Trains."

Mr. Wm. T. Taylor : "Notes on the Water Supply of Greater New York."

Mr. James Tonge : "Uses of the Hydraulic Mining Cartridge."

The Council have awarded premiums to the following for the papers contributed by them as indicated in the foregoing list :—

The President's Gold Medal to Mr. A. S. E. Ackermann.

The Bessemer Premium, value £5 5s., to Mr. A. S. Buckle.

The Clarke Premium, value £5 5s., to Mr. S. M. Dodington.

A Society's Premium, value £2 2s., to Mr. James Tonge.

The Premium, value £3 3s., for Members of Affiliated Societies, to Mr. R. H. Cunningham (Crystal Palace Engineering School).

The Council will always be glad to consider offers of papers on engineering subjects from members and their friends. " Instructions to Authors " in preparing papers may be had from the Secretary.

Appointments Register.

Twenty applications for assistants have been received during the year, for which eighty-five candidates have been put forward, nine of whom have been appointed. Twelve other candidates have notified the Secretary that they have obtained posts, and there are three vacancies open at the date of issuing this report.

Council and Officers for 1915.

The postal ballot for the election of the Council and Honorary Officers for the ensuing year has resulted in the election of the undermentioned :—

President : Norman Scorgie.

Vice-Presidents : Percy Griffith, Henry C. Adams.

Members of Council : Henry Adams, Charles T. Walrond, S. Cowper Coles, B. H. M. Hewett, F. H. Hummel, G. A. Becks, F. L. Ball, W. B. Esson, G. O. Case, W. Noble Twelvetrees.

Associate Member of Council : C. E. May.

Hon. Secretary and Hon. Treasurer : D. B. Butler.

The thanks of the Society are due to the Scrutineers of the ballot lists, Messrs. G. Noble Fell and Ernest King, for their services.

Status of the Profession.

A Committee specially charged with the duty of dealing with questions of professional etiquette, minimum fees and similar matters bearing on the status of the engineering profession, has done much useful work during the past year. Members are specifically invited to send in particulars of cases in which they think the usually understood rules of professional etiquette have been violated to the prejudice of the profession generally or of

individual members. Such information will be treated confidentially and should be sent to the Secretary, marked on the envelope "Status; Confidential." It will then be submitted unopened to the Council.

Fellowship Examination.

This consists of two parts, (I.) Scientific, (II.) Practical. Exemption from the first part is granted to holders of certain University degrees or diplomas, or to those who have passed the Associate Membership Examination of the Institution of Civil Engineers. The practical part of the examination is divided into thirty-one subjects, each representative of a distinct branch of engineering. A pass in one branch at least is compulsory, but more than one may be taken and the successes will be recorded on the certificate. Under the revised Articles of Association the Council now have power, in exceptional cases, to admit candidates to Fellowship without Examination.

Privileges of Membership.

The Council desire to remind the members of the benefits of membership of the Society, some of which are mentioned below. These advantages should be an incentive to non-members to join the Society and they are here mentioned so that members may bring them to the attention of their engineering friends.

Business Directory.—A register is kept on which is recorded the name, address, qualifications, and principal work of all members supplying the necessary information. The Directory is used when inquiries are made for engineers who can undertake some special class of work whether in a consultative or other capacity as a principal. No fees are charged in connection with this work.

Appointments Register.—This index of men desiring appointments has been extensively used with satisfactory results. Members seeking new appointments and employers in need of engineering assistants are recommended to make use of this register, detailed particulars of which may be had from the Secretary.

Legal Advice.—The Society bears the cost of providing for members free legal advice on professional matters only. The Council reserve to themselves the right to publish in the Journal the questions and answers, without names, if they consider them to be of general interest.

Advice on Patents, Etc.—Members may also obtain through the Society free advice on patents, trade marks, designs, and copyright.

General Information.—The Secretary and his staff will, at all times, assist members with such general information on engineering matters as may be possible, no charge being made for this service.

Library.—The Library of the Society contains the Transactions of the principal engineering societies, the current engineering journals and magazines, and a number of useful books. It has recently been re-arranged so as to facilitate reference by members.

Offices.—Members can make use of the Society's offices during the usual hours for the purpose of reading and writing, or for interviews.

Premiums.—Valuable premiums are offered every year for papers of sufficient merit read before the Society and published in the JOURNAL.

17, VICTORIA STREET, WESTMINSTER.
14*th December,* 1914.

INDEX TO TRANSACTIONS, 1910-14.

The date following each title indicates the year of publication, and the page reference is to the volume of Transactions for that year.

NOTE.—A complete index to the Transactions of the old Society of Engineers will be found in the last volume published by that Society, and the volumes of Transactions of the Civil and Mechanical Engineers' Society are also indexed.

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